REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1995	Final

4. TITLE AND SUBTITLE

FY96 Materials and Processes
Technology Area Plan (TAP)

5. FUNDING NUMBERS

PR 9993
TA 00
WU 00

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Materials Directorate
Wright Laboratory
Air Force Materiel Command
Wright Patterson AFB, OH 45433-7734

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Materials Directorate
Wright Laboratory
Air Force Materiel Command
Wright Patterson AFB, OH 45433-7734

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

WL-TR-96-4000

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)* The Materials and Processes Technology Area Plan (M&P TAP) describes the research and development activities performed by the Wright Laboratory's Materials Directorate (WL/ML) at WPAFB, OH. WL/ML is responsible for developing M&P technologies for all Air Force aircraft, spacecraft, and missiles systems. The M&P for Structures, Propulsion, and Subsystems thrust of the M&P TAP describes the development of technologies utilizing advanced composite materials, lightweight aluminum and titanium alloys, high temperature intermetallics, and improved fluids, lubricants, and coatings. Applications include airframe and engine retrofits, high speed aircraft, spacelift, missiles and satellites. The M&P for Electronics, Optics, and Survivability thrust of the M&P TAP describes the development of materials for high temperature semiconductors and superconductors, advanced infrared detectors, non-linear optical devices, and laser hardening. Applications include high power radar and avionic systems, infrared countermeasures, and sensor and aircrew laser protection. The M&P for Systems and Operational Support thrust of the M&P TAP describes the development of nondestructive inspection (NDI) techniques and repair of composite and LO materials. It also describes ML's interface with all Air Force fielded systems through logistic centers and system project offices (SPOs) and by conducting electronic and structural failure analysis.

14. SUBJECT TERMS Materials, Processing, Carbon/Carbon, Metallics Organic Matrix Composites, Nondestructive Evaluation, Ceramics, Fluids, Lubricants, Electronics, Optics, Survivability, Manufacturing Science, System Support

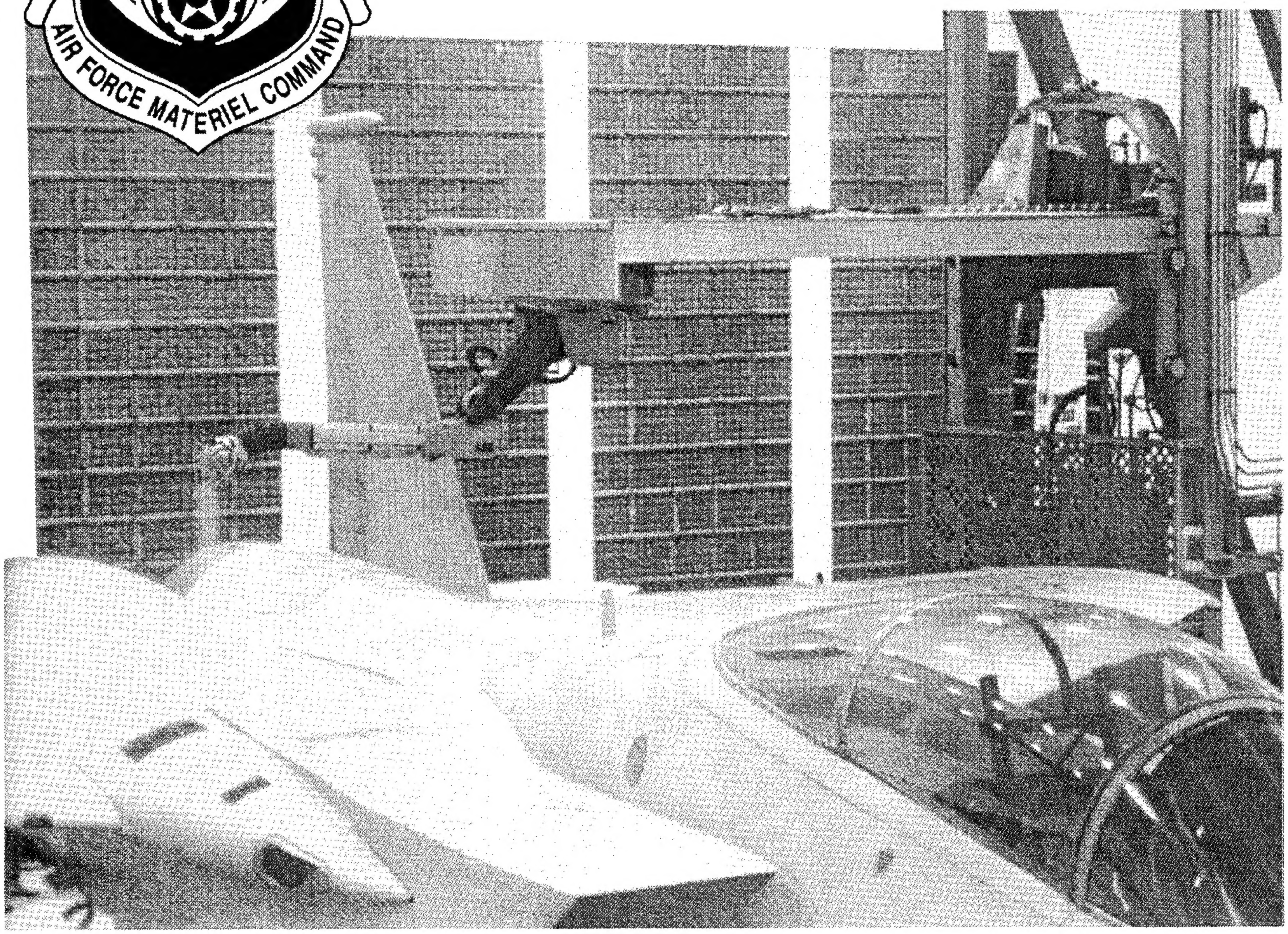
15. NUMBER OF PAGES 31

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

WL-TR-96-4000

FY 96 MATERIALS & PROCESSES TECHNOLOGY AREA PLAN



HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE AND TECHNOLOGY
WRIGHT-PATTERSON AFB, OHIO

Note: This Materials and Processes Technology Area Plan is a planning document for the FY96-02 Science and Technology (S&T) program and is based upon the President's FY96 Budget Request. It does not reflect the impact of the FY96 Congressional appropriations and FY96-02 budget actions. You should consult WL/XP, (513) 255-4843, for specific impacts that the FY96 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 Aug 1995.

... about the cover

Pictured on the cover is the Air Force's F–15 being painted in the Small Aircraft Finish Application and Robotic Installation (SAFARI) at Warner Robins Air Logistic Center (WR-ALC). The Materials and Processes Technology Area is a key team member in the development of reliability, maintainability and supportability technologies for life management of aging systems and for providing enabling technologies, risk management and risk reduction to meet specific future systems requirements. Particular life management of aging systems emphasis is being given to depainting and painting, corrosion detection and prevention, extended system life prediction, nondestructive inspection, repair and environmental regulation compliance. Some of the materials and processes (M&P) being developed and areas of technical support activities relating to life management of aging systems are as follows:

Depaint: Materials and techniques that meet increasing environmentally regulations.

Paint: Materials and techniques for longer life and environmental compliance.

Corrosion Protection: Corrosion resistant structural materials and coatings.

Nondestructive Inspection:

Early Detection of hidden corrosion.

Second-layer crack detection under fasteners.

Rapid, low cost, large area inspection of composites.

Advanced nondestructive evaluation of turbine engine disk inspection.

Enhanced limited angle computed tomography of liner/case inspection of aging ballistic missile motor cases.

Pollution Prevention: All facets of Processing, Fabrication, Maintenance, and Disposal.

Extended System's Service Life: Models and materials for life prediction / life extension.

Repair:

Bonding technology using composite repair patches for cracked metallic structures.

C-141 weep hole repair support.

More durable composite patch repairs via advanced modeling methods to determine the state of stress in both metal substructure and composite laminate.

Upgrades And Retrofits:

Improved fatigue performance and stress corrosion resistant aluminum alloys.

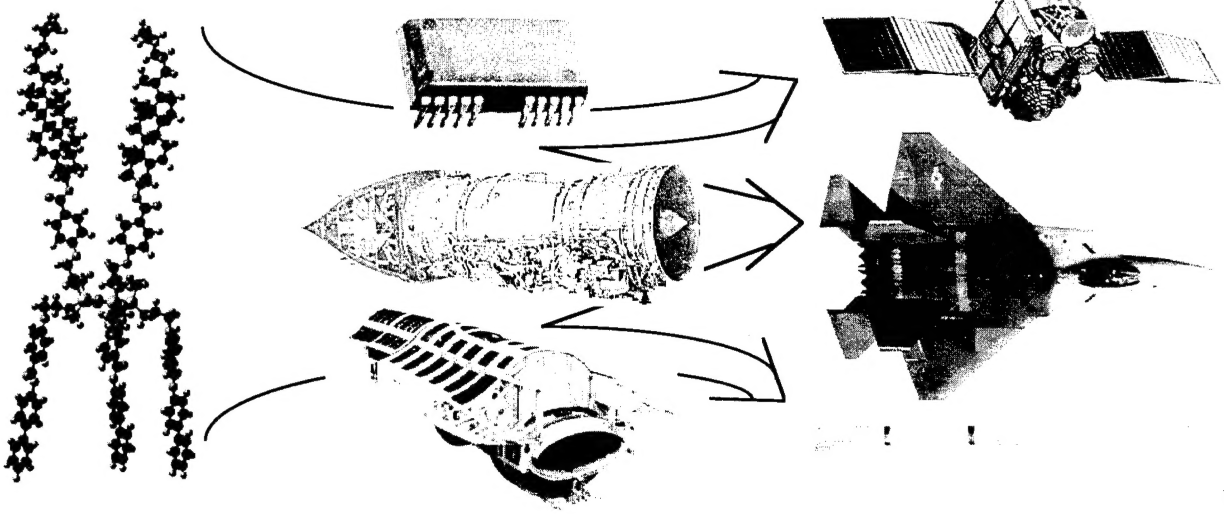
More durable polymeric coatings for extended life of IR windows and IR domes.

Alternate heatshield materials for aging ballistic missile fleet - thermal and mechanical characterization of aging heatshield materials.

Improved ester based gas turbine engine oil for fleet maintenance reduction.

Infrared countermeasure materials to keep current fleet viable in the face of a more sophisticated technologically evolving threat.

MATERIALS & PROCESSES



"MATERIALS AND PROCESSES TO MEET THE CHALLENGE"

VISIONS & OPPORTUNITIES

The Materials & Processes Technology Area Plan addresses materials and process (M&P) development and support for all Air Force current and future systems. The impact of these technologies is pervasive to all systems. More importantly, materials and processes often represent the limiting factor in system cost, performance, maintenance, and sustainability. The importance of the area is reflected in the Department of Defense (DoD) priorities. The Undersecretary of Defense for Research and Engineering (USD/DDRE), Dr. Anita Jones, has stated that "the top four priorities for DoD Science and Technology are: Information Technologies, Sensors, Materials, and Affordability." While materials are specifically identified, materials development and processing technologies are also critical elements for each of the other priority areas. This is further reinforced by analysis of Mission Area Plan's (MAP) deficiencies and Technology Planning Integrated Product Team's (TPIPT) technology needs.

The challenge is to provide better and more affordable materials and processing support to operations and maintenance, while developing the materials and processes to help meet potential readiness problems in 5 to 10 years. The opportunities lie in responding to the need to replace hardware in aging systems, in the modifications / upgrades that will occur and in critical environment issues such as pollution prevention, corrosion control, and nondestructive inspection of environmentally caused defects. We can utilize these lower risk applications to qualify and gain production experience on new materials and processes and thus reduce their risk in 21st century systems. Our vision is whether the challenge is aging systems or preparation for next century systems, we will have "the materials and processes to meet the challenge."

We will accomplish this by:

- Conducting far, mid, and near-term, high payoff M&P research and development, and implementing technologies wherever possible on nearer term modifications / upgrades / sustainment activities.
- Developing M&P technologies directly related to improved maintenance that, in themselves, become baseline technologies for reduced maintenance and improved reliability in next generation systems.
- Providing in-house M&P expertise and systems support for the Air Force Product Centers and maintenance and repair centers.

To respond to our customer's needs in a period of downsizing, we will:

- Maintain a world-class research organization in a selected number of M&P areas vital to future Air Force capability needs and be "one phone call away" from national and international experts in other areas.
- Have quality facilities in which to perform the excellent work expected of us.

Our philosophy in achieving the above will be to:

- Conduct in-house research in order to;
  - pick the right technologies to exploit
  - be educated buyers of contracted technology.
- Place collocated engineers with system program offices (SPOs) to:
  - identify technology needs to the Materials Directorate (WL/ML)
  - identify opportunities in preplanned product improvements to WL/ML
  - help SPOs fix their current problems by providing materials and processing solutions.
- Contract with industry to ensure that industry possesses technology essential to the Air Force and to help maintain a vital industrial base.
- Continue to make our customers aware of new materials and processes that solve their current problems or meet their future needs.
- Work with Wright Laboratory Customer Focus Integrated Product Teams (CFIPTs) to maintain a balanced program that addresses all Air Force Product Center needs.
- Maintain a cognizance of Mission Area Plans and direct involvement in the Technology Planning Integrated Product Teams to ensure that we can insert new technology when needed into new / upgraded weapon concepts.
- Interact with other service science and technology organizations to:
  - coordinate and share progress
  - resolve overlap and exploit opportunities for cooperation
  - provide technical development in areas where we have the sole expertise or technical lead.

This plan has been reviewed by all Air Force laboratory commanders / directors and reflects integrated Air Force technology planning. We request Air Force Acquisition Executive approval of the plan.

Richard R. Paul

RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer

David A. Herrelko

DAVID A. HERRELKO, Colonel, USAF
Commander
Wright Laboratory

CONTENTS

INTRODUCTION

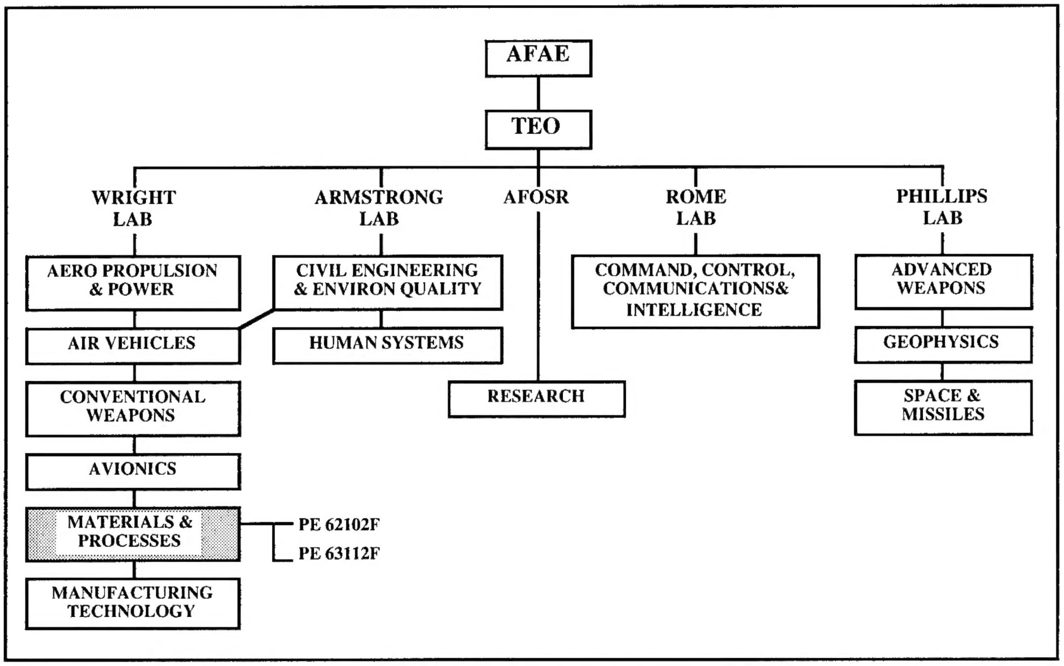


Figure 1: Air Force Science & Technology Program Structure

BACKGROUND

The Materials and Processes Technology Area, highlighted in Figure 1, is that part of the Air Force Science and Technology (AF S&T) program responsible for developing materials, cost-effective processes, non-destructive evaluation technology and intelligent processing of advanced materials to support the entire Air Force mission.

Over the years many outstanding contributions have been made by this area, including superalloys for high-temperature turbine engines, ultra-high purity silicon for infrared detectors, permanent magnets for microwave and power generation and conditioning applications, advanced composites for aerostructures, carbon-carbon nozzles and nosetips for ballistic missiles, high temperature lubricants, and thermal control coatings for spacecraft. Over the past year, this area continued to provide outstanding contributions to the Air Force and many of these are highlighted under the three thrust areas. A particular noteworthy contribution was the development and transition of a new high temperature advanced composite material, AFR700B, to the F-117A stealth fighter. For this, a team of engineers within the Materials and Processing (M&P) Technology Area received the first Lt. Gen. Thomas R. Ferguson, Jr. Award for Excellence in Technology Transition.

Since materials and processing technology is often a limiting factor in achieving desired mission capabilities, close working relationships are necessary to define user needs and to supply the level of user support required. To achieve these relationships, we are actively working within the Technology Master Process and we maintain collocated engineers at Systems Program Offices (SPOs). In addition, we provide quick reaction support to resolve operational field maintenance problems with materials as they occur. These activities help us to identify technology needs of current systems and for the next generation systems.

The current research and development program is focused on providing the M&P technologies needed for both system upgrades / modifications and advanced systems, including propulsion, structures, electronics, optics and electro-optics, all with an emphasis on performance, affordability, and supportability. These system concepts evolve informally through direct user interactions and formally through the Technology Master Process (TMP) which has Center Technology

Council (CTCs) technology needs submitted by the Air Logistic Centers and Air Force Test and Engineering Centers, Mission Area Plans (MAPs) deficiencies prepared by the Major Commands, and the Technology Planning Integrated Product Teams (TPIPTs) needs prepared by the Air Force Materiel Command in cooperation with Air Force users.

Based upon the TMP process which includes threat assessment, capability needs and technological opportunities, AF S&T funds are allocated to the M&P Technology Area as shown in Figure 2. All funding figures reflect the President's FY96 Budget Request. The program defined in this Technology Area Plan is subject to change based upon possible congressional action.

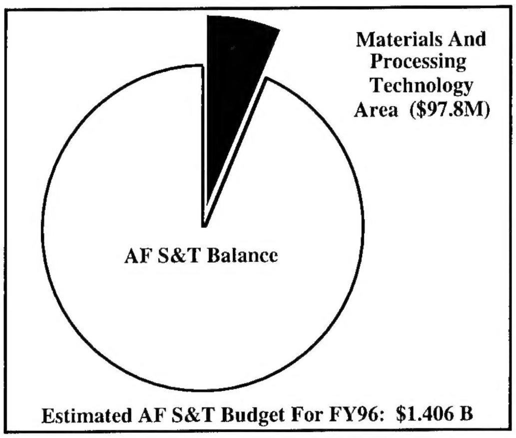


Figure 2: Materials & Processes S&T vs. AF S&T

From reviewing the MAPs and TPIPTs, it is estimated that 83% of the MAPs and TPIPTs have deficiencies or technology needs in which the M&P Technology Area can play a major role in resolving. Specifically, the technologies being developed can play a major role in resolving 33% of the deficiencies and technology needs identified from the MAPs, TPIPTs, and CTCs. The TPIPTs with the most technology needs within the M&P Technology Area are Air to Surface, Counter Air, Missile Defense, Information Warfare, and the Environmental Safety and Occupational Health TPIPTs. The MAPs with the most deficiencies in the M&P Technology Area are Close Air Support, Counter Air, Air Force Special Operations Command Roadmap, Provide Mobility In Denied Territory, Combat Delivery, Electronic Combat, Military Satellite Communications, and Nuclear Deterrence MAPs. The user needs on which the M&P Technology Area can have an impact are predominantly related to propulsion systems; communication, computing, navigation, and datalink type devices; offensive and defensive sensors; lightweight structures; lightweight high temperature structures; and pollution prevention. The difficult task that lies ahead is in prioritizing the needs to focus limited funds on those needs most critical to the Air Force.

To meet systems requirements that drive materials and material processing research and development, the Materials and Processes Technology Area is organized into three key technical thrusts listed in Figure 3.

Technical Thrust Numbers And Titles
1 Materials And Processes For Structures, Propulsion, & Subsystems
2 Materials And Processes For Electronics, Optics, & Survivability
3 Materials And Processes For Systems And Operational Support

Figure 3: Major M&P Technology Thrusts

These Thrusts are structured to meet Air Force capability needs and are reviewed and revised periodically to reflect changing priorities. **Thrust 1** is the largest effort in the M&P Technology Area and covers development of materials and processes for a wide range of aircraft, space, and missile applications requiring characteristics such as load bearing, thermal management, lightweight, reduced life cycle cost, signature control and lubrication. **Thrust 2** includes electronic materials and material processes to meet requirements for advanced avionics, communications, reconnaissance, surveillance, intelligence and electronic combat as well as electromagnetic materials for transparencies and laser hardening for personnel eye protection, sensors, and aircraft and spacecraft structures. **Thrust 3** is the primary interface between the M&P Technology Area and users. It provides nondestructive inspection / evaluation (NDI/E) techniques and devices, on-site personnel in SPOs, component material failure analyses, and develops data to transition materials to those organizations that develop, operate, and

maintain systems. This thrust also has the lead to reduce by 50% the use of hazardous toxic materials in material processing. Figure 4 shows the relative emphasis of these thrusts by distribution of AF S&T funds.

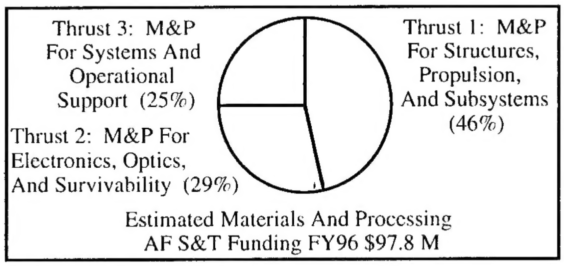


Figure 4: Major Technology Thrusts

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

Relationship To Other AF TAPs - Since the M&P Technology Area is broadly based and supports the entire Air Force, it is closely related to many other S&T technology areas. For example, this Area has joint initiatives with the **Aero Propulsion & Power** Area for the Integrated High Performance Turbine Engine Technology (IHPTET) program, the **Avionics** Area in M&P for electronic devices, the **Air Vehicle** Area in modern control theory of new material metal forging processes, the **Space & Missiles** Area in space and propulsion M&P, and the **Research** Area in basic materials research. In addition, the **Manufacturing Technology** Area scales up materials and innovative materials processing technologies developed by this area.

Industrial Programs - The Air Force provides leadership and vision for the aerospace industry investment in M&P research. This is stimulated in part by devoting a great deal of energy interfacing with industry to provide direction and focus. The M&P Technology Area leverages industry investment to maximize return on Air Force investment and ensure critical mass funding levels. Typically, industry investment is more production driven, while Air Force investment addresses research needs of new and fielded systems. The M&P Technology Area strategy is to reduce investment in areas where there already is considerable industry Independent Research and Development (IRAD) investment. Thrust 1, Materials and Processes for Structures, Propulsion and Subsystems, has demonstrated this strategy by providing international leadership in technology insertion of organic composites for the last two decades. In areas such as laser hardening, covered by Thrust 2 Materials and Processes for Electronics, Optics and Survivability, industry investment is small resulting in a considerably larger investment being needed within the M&P Technology Area to meet future requirements. The number and total funding of aerospace related materials and processes projects being funded through the FY94 IRAD program by industry is listed in Table 1. Note that one project may be related to more than one thrust, thus the total number of projects and funding is not cumulative. Aerospace related M&P technology represents approximately 958 projects, or 17% of the total IRAD effort.

Table 1: Summary of Related Aerospace Materials and Processes IRADs by TAP Thrusts

M&P Thrust	Number Of IRADs	Funding ($M)
1: Structures, Propulsion, And Subsytems	568	$375
2: Electronic, Optics And Survivability	282	$171
3: Systems And Operational Support	212	$114
Total Number Of Unique * Programs	958	$630
(* Numbers Do Not Add Since Some Programs Relate To More Than One Thrust)		

The M&P Technology Area also actively supports small businesses through actively awarding small business set-asides, small business innovation research (SBIR) and small business technology transfer (STTR) contracts. This approach leverages M&P Technology Area funding in seeking unique breakthrough technologies to fulfill Air Force technical and mission needs. Of particular emphasis are the areas of environmental compliance, modeling and simulation, novel processing methods, biological films for optical coatings, nondestructive inspection, superconducting M&P, electronic packaging, and biodegradable paint removal materials. Table 2 lists the number and total funding of

ongoing Phase I SBIRs and Table 3 does the same for Phase II SBIRs. There were three STTR awards relating to technical Thrust 1 for structural and propulsion materials totaling $298,316. Total awards to SBIR Phase I, Phase II, and STTRs for FY94 equaled $10,778,100. Awards for FY95 SBIRs are still in process as of this report submittal.

Table 2: Summary of Phase I SBIRs by TAP Thrusts

M&P Thrust	No. SBIR Phase I	Funding ($)
1: Structures, Propulsion, And Subsytems	13	$777,622
2: Electronic, Optics And Survivability	7	$418,618
3: Systems And Operational Support	7	$415,503
Total	27	$1,611,743

Table 3: Summary of Phase I I SBIRs by TAP Thrusts

M&P Thrust	No. SBIR Phase II	Funding ($)
1: Structures, Propulsion, And Subsytems	7	$5,053,253
2: Electronic, Optics And Survivability	4	$2,637,797
3: Systems And Operational Support	2	$1,475,307
Total	13	$9,166,357

A collaborative effort with Think Along Software Incorporated to develop materials process models is also contributing to medical research. Their cooperation through a SBIR project led to the development of an artificial intelligence tool being used by both the UCLA Medical School and the USAF Medical Center at Wright-Patterson Air Force Base to investigate the human body's healing process. This tool will help medical researchers find ways to assist the body's immune system in healing wounds faster and with less complications.

As exemplified by the SBIR project involving the UCLA, the M&P Technology Area actively seeks participation from universities in the advancement of materials sciences. Currently the M&P Technology Area has five educational partnership agreements with regional schools from which scientists and students are collaborating on research. The universities represented are Dayton, Wright State, Northern Kentucky, Cincinnati, and Ohio State.

International Programs - There are presently eight international contracts valued at $1.2M. The two primary efforts are in the areas of Large Area Inspection Systems and Laser Induced Chemical Vapor Deposition of Thin Film Materials. The Large Area Inspection Systems program complements similar efforts with U.S. companies and brings in an alternate approach to solve a major Air Force problem of how to economically inspect composite aircraft wings in service. The second program provides access to a creative approach that has potential for improved life and performance of high wear components. The other six programs are each $25K efforts with the Former Soviet Union.

In addition to the above international contracts, international Memoranda of Understanding (MOU) are maintained in tactical laser hardened materials and in titanium alloys. Data Exchange Agreements (DEA) exist for the following areas : 1) fluids and lubricants technology, 2) nondestructive evaluation, 3) materials, measurements and characterizations, and 4) materials and processes for military applications. All of these areas are high priority that support our customer needs and enable us to follow international developments in these areas and bring these technologies to bear on our needs.

Other DoD and Government Agencies - The M&P Technology Area is thoroughly coordinated through the DoD Joint Directors of Laboratory (JDL) Technology Panel for Advanced Materials. The Air Force chairs 2 of the 11 subpanels and is represented on 8 of the other 9 subpanels. The Air Force does not participate on the Armor Subpanel. The panels chaired by the Air Force are the Special Functional Materials and Bio-molecular M&P panels. Even though coordination already existed among the services, a more

comprehensive coordination has been realized through the JDL Subpanels.

We are also actively working with the National Materials Advisory Board and National Science and Technology Council to identify critical national M&P issues. This ensures that critical USAF M&P technology is included in the national investment strategy.

CHANGES FROM LAST YEAR

During strategic planning activities, five areas were identified for increased strategic emphasis. These five Strategic Emphasis Areas (SEAs) will focus and prioritize activities across the M&P Technology Area to: provide demostratable near-term benefits for our highest priority customers; be the areas in which the M&P Technology Area will add resources; and assure the technology areas presence in DoD and national arenas is recognized. The five SEAs are:

- M&P for Space and Missile Systems
- M&P for Life Management of Aging Systems
- M&P for Pollution Prevention
- Advanced Processing Technology
- Dual-Use Applications for Aerospace M&P.

Three of these areas (Space, Aging Systems, and Pollution Prevention) were selected for increases in the FY96 POM.

The Space and Missile SEA established a partnership with the Phillips Laboratory (PL) in which 20% of the M&P Technology Area's 6.2 core technology budget is to be dedicated to support the space and missile sector by FY97. Additionally, a joint investment / program strategy was established and an organizational infrastructure was implemented to ensure the continued health of the partnership.

The Life Management of Aging Systems SEA covers a broad range of technologies such as corrosion detection, characterization and protection; durable composite patch repair of cracked metallic structures; long life coatings for infrared windows and domes; and alternate heatshield materials and booster inspection methods to enable Air Force systems to be maintained in the active inventory beyond their planned service life. Also, improved, environmentally compliant, long-lasting M&P for painting and depainting is a specific technology that will be provided.

The Pollution Prevention SEA has a goal to reduce the purchase of 17 Environmental Protection Agency (EPA) toxins by 50% by the end of 1996 from the 1992 baseline for all Air Force operations and their contractors. Another goal for the Pollution Prevention SEA is to reduce hazardous material waste disposal 25% from the 1992 baseline by 1996 and by 50% by the end of 1999. Particular focus is on cleaning and degreasing volatile organic compounds (VOCs), ozone depleting chemicals (ODCs), paint stripping, protective coatings, and metal bearing waste.

The Advanced Processing SEA is a pervasive technology area with great payoff. Focused advanced processing efforts are underway for cost reduction in low volume production runs through the use of sensors and nondestructive inspection, and breakthrough opportunities such as pulse laser deposition (PLD) of tribological materials.

The Dual Use SEA actively promotes technology transfer by working with industry through the use of cooperative research and development agreements (CRDAs). The M&P Technology Area has 18 active CRDAs with 4 more in the signature phase and 20 others under consideration covering such areas as scale-up of processing techniques, publishing engineering data, and making computer models user friendly for wider distribution. Of significance was the transfer of software, data, material testing techniques and advanced process engineering procedures to a network of five aluminum extrusion and 16 die-making companies. An engineer within the M&P Technology Area received the 1994 Federal Laboratory Consortium Award for Excellence in Technology Transfer for this activity. This effort has had a significant positive impact on the economic well-being of the extrusion industry with the companies estimating a savings of $25M over 5 years. Similar activities for casting metals is underway with small foundry companies.

PROGRAM DESCRIPTION

Thrust 1: Materials & Processes for Structures, Propulsion And Subsystems

The overall objectives of this thrust are to provide new materials and processes for:

1) Structural applications for aircraft, missiles, launch systems and satellites
2) Structural applications for propulsion systems
3) Nonstructural applications for all Air Force systems.

Materials and processes (M&P) currently under development or transition includes carbon-carbon for electronic thermal management, lightweight satellites and for re-entry vehicle (RV) nosetips, leading edges, and heatshields; an aluminum alloy for reduced aircraft and spacecraft weight; titanium and nickel aluminides for hypersonic vehicles, advanced engines, and improved system reliability; reduced processing cost of advanced nonmetallic composites, as well as higher temperature composites to replace metallics for weight savings; nonlinear optical and conductive polymers for advanced communication and computing devices; and advanced hydraulic fluids, low friction films for bearings, advanced lubricants for subsystems and thermal control coatings for space vehicles. This area is coordinated with the other services through the Joint Directors of Laboratory (JDL) Technology Panel for Advanced Materials structural, high temperature, special function, bimolecular, advanced processing and signature control materials subpanels.

USER NEEDS

Thrust 1 is developing technologies that directly support needs of the Air to Surface, Counterair, Special Operations, Mobility, Missile Defense, Strategic Deterrence, and Space Forces Support Technology Planning Integrated Product Teams (TPIPTs). Similar Mission Area Plan (MAP) deficiencies supported are for the Close Air Support; Strategic Attack, Counterair, the Air Force Special Operations (AFSOC) Roadmap, Provide Mobility in Denied Territory, Missile Warning, Military Satellite Communications (MILSATCOM), and Nuclear Deterrence MAPs. A roadmap for Thrust 1 is presented in Figure 5 and an illustration of the correlation between key technologies developed by Thrust 1 and the TPIPTs and MAPs is presented in Figure 6. The largest number of identified user needs for Thrust 1 are for far-term aircraft, spacecraft, and engine applications regarding range, speed, fuel efficiency, and weight. These broadly based needs from a majority of TPIPTs and MAPs are directly impacted by **lightweight and high temperature M&P for structures and propulsion systems** such as advanced metallic alloys, and metal-, ceramic-, and organic-matrix composites. There are fewer but a significant number of user needs supported by Thrust 1 technologies for new missiles, satellites, engine modifications, unmanned aerial vehicles (UAVs), and preplanned product improvements (P3I) in the near- to mid-term.

Modifications / P3I plans are for improved life requirements in which materials play an important role. Airframe structure upgrades using lightweight aluminum and titanium alloys as well as organic and metal matrix composites will improve life as well as performance (range / fuel efficiency) in existing systems. A specific example is the RC-135 which has a plan to reskin the wings by 2005 with smart designs using lightweight metallic alloys, organic and metal matrix composites. This program would provide the opportunity to extend the range, loiter, and life of this reconnaissance asset. Other AF reconnaissance assets also have similar requirements which will improve their range, on-station-time, and life. Also, low cost metal and composite process techniques utilizing intelligent process models, controls, and sensors can reduce the acquisition cost of new systems as well as retrofits. This has been demonstrated previously by using an advanced organic matrix composite developed by the Materials Directorate (AFR700B) in a retrofit of the F-117A at Sacramento Air Logistics Center (SM-ALC). A new material substitution that utilized intelligent process automation techniques during processing has reduced the acquisition cost of F-117A trailing edge components by 50% and offers a three fold extension in component life.

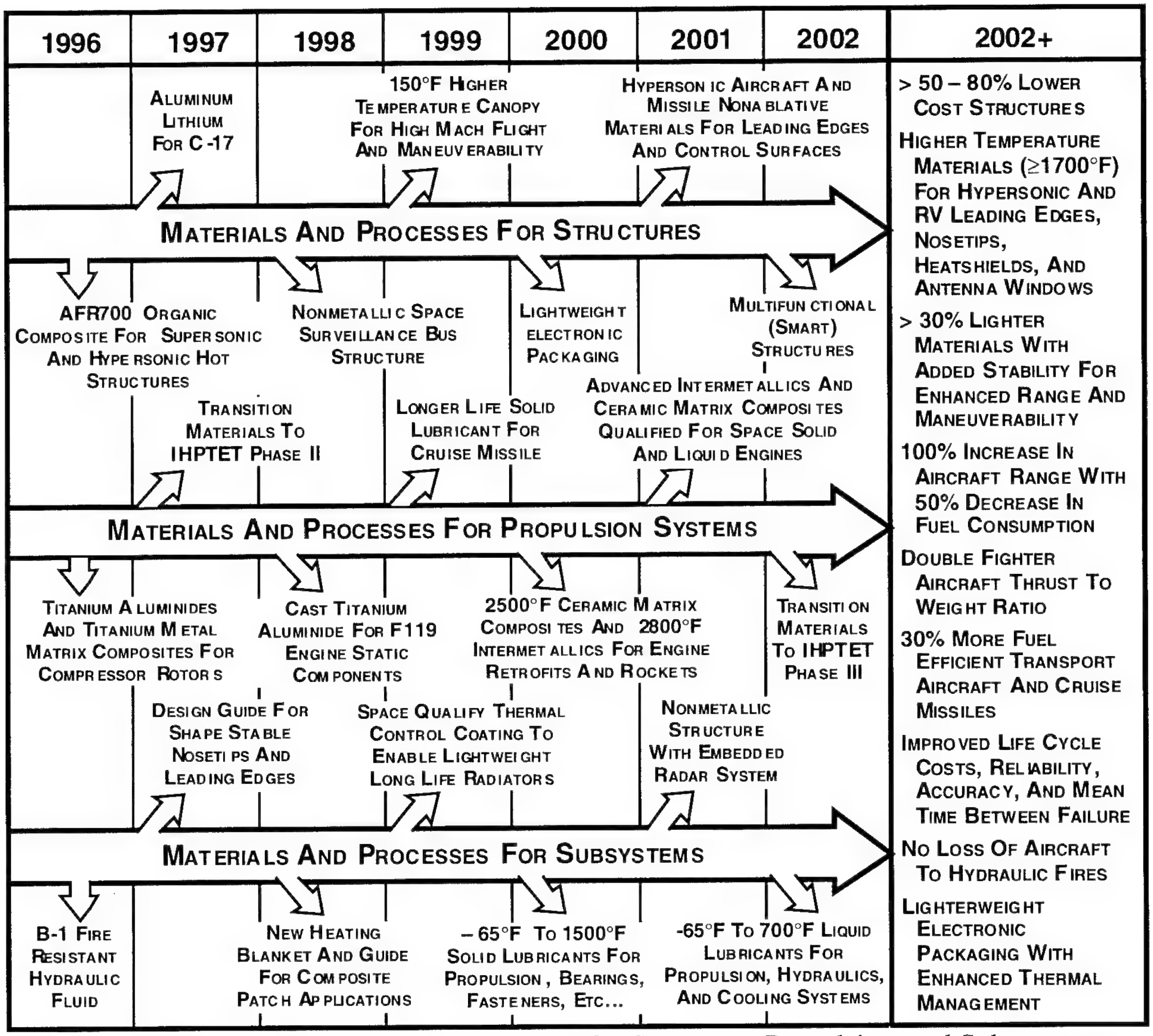


Figure 6: Thrust 1 - Materials and Processes for Structures, Propulsion, and Subsystems

High strength, lightweight organic and ceramic matrix composites are required with inherent low observable (LO) properties to reduce aircraft radar cross section (RCS) for retrofits and new systems capability. TPIPT system concepts requiring **LO / signature control technologies** are 21st century fighter; dual role missile; UAV / RPV (remotely piloted vehicle); next stealth attack, forward air control (FAC), airlift and special operations aircrafts; and Defense Meteorological Satellite Program (DMSP). MAPs with signature control requirements are: Counter Air, Close Air Support, Electronic Combat, Rescue, Strategic Attack, Provide Mobility In Denied Territory, Surveillance and Reconnaissance, Special Operations Roadmap and Counterspace.

As stated previously there are a significant number of requirements for aircraft and spacelift **propulsion systems**. While developing M&P to enable the next generation of engines and rockets, there are several near- and mid-term opportunities to insert emerging technologies into tactical missiles and current propulsion systems thorough modifications, retrofits and P3I. Lightweight high temperature engine materials (advanced metallic alloys and intermetallics, metal-, ceramic- and, organic-matrix composites) as well as nonstructural materials (fluids, lubricants and seals) are being developed to meet near- and mid-term TPIPT needs. These needs include high cycle fatigue (HCF); thrust vectoring; high efficiency fans; reaction jets for directional control; low cost hypersonic, missile

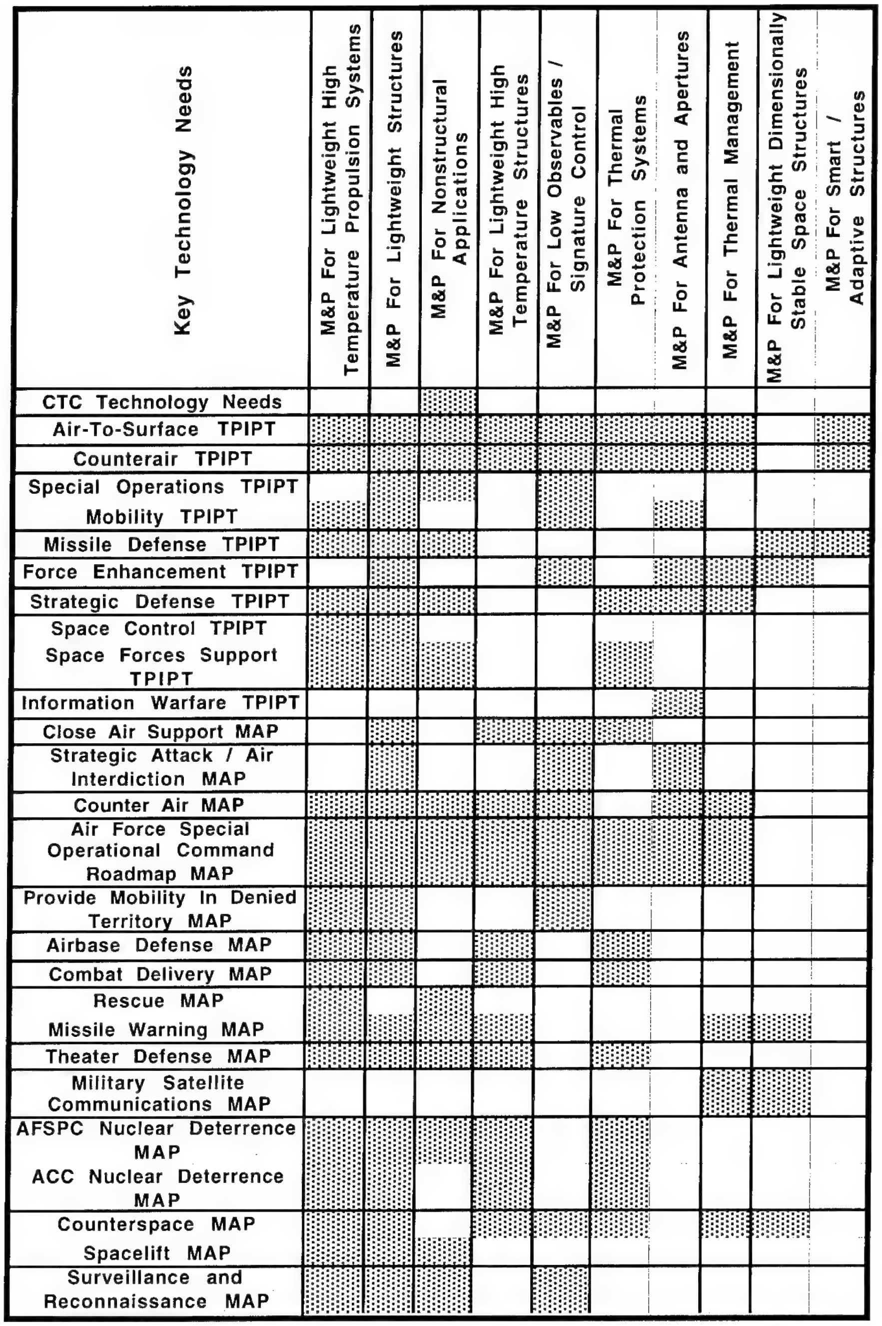


Figure 6: Thrust 1 Key Technologies For MAPs & TPIPTs

and space boosters; low-cost integrated rocket/ scramjet; improved reliability; and decreased size, weight and complexity.

The lightweight high temperature structural materials area initiated by the M&P Technology Area in support of the National Aero Space Plane in the late 1980s continues to support 21st century systems requiring high mach flight, enhanced maneuverability, and very high angle of attack (AOA). These nonablative primary airframe structural materials (advanced metallics, organic and ceramic matrix composites) will lower the systems weight, complexity, cost, and maintenance while enhancing range, payload, and maneuvering capabilities. TPIPT systems concepts identified for integration of **lightweight high temperature structures** are next stealth attack and FAC aircrafts; hypersonic bomber and attack aircraft; dual role, 4-pi, mach 8-10, and mach 4-6 missiles; and glide weapons. MAPs with lightweight high temperature structural requirements are Close Air Support, Counter Air, AFSOC Roadmap, Airbase Defense, Missile Warning, Counterspace, and Nuclear Deterrence.

Hypersonic and ablative structures (nosetips, and heat shields) require **thermal protection systems** with high temperature structural materials (advanced metallics, metal and ceramic matrix composites). System performance needs are for reduced weight, cost, cooling, complexity, length-to-diameter (L/D) design ratios, and installation requirements while increasing range, AOA, and durability. Specific TPIPT concepts requiring these materials are hypersonic bomber and attack aircraft, global response systems (semi-orbital UAV), dual role missile, re-entry vehicles and spacelift vehicles. MAPs with thermal protection systems needs are: Combat Delivery, Close Air Support, AFSOC Roadmap, Nuclear Deterrence, Counterspace, and Airbase Defense.

Along with the increasing need for supersonic / hypersonic flight and very high AOA is the need for continuous, accurate, targeting and communication. Materials being developed (carbon-carbon, ceramic matrix composites and organic matrix composites with highly conductive fibers) for larger more advanced **antennas and apertures** that have LO characteristics and are conformal will allow real-time, continuous tracking and data relay, ground uplink-downlink telemetry, global positioning satellite (GPS) update, and synthetic aperture radar (SAR) tracking. The TPIPT system concepts identified for antenna and aperture materials technology are the next stealth attack and FAC aircrafts, hypersonic bomber and attack aircrafts, hypersonic attack and standoff fast reaction weapons, UAV decoy, kinetic energy weapons, dual role, mach 4-6 air breathing and mach 8-10 missiles, glide weapons, MILSATCOM, ultra high frequency (UHF) adaptive arrays, re-entry vehicles, and mobility multiband antennas and radios. MAPs with antenna and aperture needs are Strategic Attack and Counter Air.

Space surveillance and communication satellites have utilized advanced structural and nonstructural material (lubricants and thermal control coatings) for years. To exploit space in the future, the AF will have to rely on low cost, reliable means of placing satellites in orbit. Lighterweight, high performance organic- and metal-matrix composites integrated into satellites will improve the mass fraction of the spacecraft by decreasing structural weight thus enabling increased payload / reduced launch cost. Lower inertial weight in orbit, combined with high modulus, low thermal expansion organic- and metal-matrix composites, and carbon-carbon can significantly increase the on-orbit performance of space based communications and surveillance platforms. These materials will also lower spacelift vehicles (rockets and single stage to orbit) costs by reducing overall payload system weight and volume.

Future space platforms also need **lightweight, dimensionally stable space structures** for precise sensor targeting and acquisition. Organic and metal matrix composites used in these areas will need to be survivable to the nuclear threat, and advanced thermal control coatings for these materials may be required to reduce weight (as opposed to thermal blankets and insulation). Nonstructural materials technology can impact constant momentum gyros and gimbal bearing platforms by developing nonoutgassing and ultralow friction lubricating (tribological) films that are usable in the high vacuum environment of space. High strength, dimensionally stable organic and metal matrix composites will be developed to meet TPIPT needs for missile warning, GPS IIF, Milstar III as well as for those deficiencies identified in the Missile Warning, MILSATCOM, and Counterspace MAPs.

For both space and tactical systems, **thermal management** of structures and electronics is becoming a critical need. Lightweight cooled and uncooled structures of carbon-carbon, conductive ordered polymers, metal matrix composites will allow innovative heat dissipation designs. TPIPT concepts requiring thermal management are hypersonic bomber and attack aircrafts, global response system, 21st century fighter, offensive directed energy weapon (DEW), mach 8-10 and mach 4-6 air breathing missiles. Similar technology is needed for small, lightweight high power density batteries as required for TPIPT ballistic missile technology and Milstar III concepts. MAPs that have thermal management needs which will require the development of structural materials and coolants are Counter Air, AFSOC Roadmap, Missile Warning, MILSATCOM, and Counterspace.

M&P technology for **smart / adaptive structures** will revolutionize how systems are designed and used in warfighting. Multifunctional materials (conducive and ordered polymers) and embedded (parasitic) sensors will enable a closed-loop feedback between a systems and the pilot for enhanced flight maneuvers, in-field structural analysis, ability to detect DEW threat engagement no matter where a laser hits a system and many others. TPIPT concepts identified for smart / adaptive structures are air-to-surface aircraft with reconfigurable flight controls, mach 8-10 global response system, the 21st century fighter and satellites for missile warning.

GOALS

The goal of Thrust 1 is to provide new M&P for aircraft, spacecraft, launch vehicles, missiles, propulsion systems, and related subsystems. Specific goals evolve around improved affordability, maintainability, and enhanced performance of current and future systems and are addressed below:

- Develop a family of affordable lightweight materials, including metals, metallic and nonmetallic composites, carbon-carbon and ceramics that can provide upgrade capability for existing aircraft, spacecraft, missile, and propulsion systems, and that can meet challenges for new systems beyond the year 2000. Included are enabling materials:
  - To meet 1700°F – 2800°F requirements for engines to double thrust-to-weight ratios of 1986 engine performance baseline
  - For spacecraft that are lightweight, dimensionally and environmentally stable (to temperature, radiation, atomic oxygen erosion, moisture), and noncontaminating to meet improved surveillance and communication requirements.
- Provide the fluids, lubricants, seals, greases, coatings, insulations, and other nonstructural materials for the subsystems on aircraft, spacecraft, and missile systems, and their propulsion systems.

Operational Capability Impact

For 40 years after aluminum became the primary material for aerospace, only incremental improvements were made in capability. It wasn't until the M&P Technology Area led the development of advanced composites that revolutionary increases in design capability were achieved. These revolutionary increases are continuing and expanding in today's and tomorrow's systems. Organic composites typically offer up to 35% weight savings, however, high processing costs often restrict their usage. Advanced processing techniques to reduce costs will increase the total portion of the airframe that can be replaced by composites.

A new canopy material under development will eliminate one of Air Combat Command barriers to extending aircraft sustained operating speeds from Mach 2.0 to 2.6. High temperature resins also are enabling composites to compete with metals in lower temperature engine applications (compressor frames, ducts) with 30% weight savings and improvements in cost, durability, and LO.

Advanced high temperature metals, such as titanium aluminide, are vital to IHPTET goals of achieving a 100% increase in thrust to weight of engines. They enable a 600°F increase in maximum compressor temperature. Also, equally as vital are high temperature liquid and solid lubricants that can operate at the desired temperature. If similar capabilities are met for the other sections of the engine, revolutionary system improvements will result for many mission areas plans:

- Fighter - Sustained Mach 3 capability, 100% increase in range, 50% decrease in fuel consumption per mission
- Transport - 30% decrease in fuel consumption, increased range and payload
- Cruise missiles - 30% decrease in fuel consumption for intercontinental range.

In spacecraft, operational improvements will be provided through stiffer materials for dimensional stability and through low volatility lubricants that will reduce outgassing around sensor systems. In the area of re-entry vehicles, the desired improvement for projected mission applications is in accuracy and alternative glide paths. These requirements are directly impacted by shape retention of leading edges. Advanced carbon-carbon materials with a 2X improvement in ablation performance are being developed to provide the desired improvements in the early 2000 time period.

Supportability

Probably the most significant supportability problem with aircraft is corrosion. One of the objectives for this thrust is to expand the use of organic composite materials to replace corrosion prone materials. Another primary supportability issue is temperature / oxidation damage to engine components. Materials being developed for high temperature needs in the 21st century propulsion systems will be evaluated as replacement hardware for existing engine overhauls/upgrades to extend life/ improve supportability. Also, damage tolerance concepts and life prediction are integral parts of all structural materials programs.

Many supportability issues are addressed by nonstructural materials such as coatings to alleviate fastener seizing in engine hardware that costs $24M/year to overhaul. 21^{st} century vehicles may have intolerable supportability problems unless the necessary fluids, lubricants and seals are developed.

Enhanced thermal management (heat dissipation) can dramatically improve operational reliability. MIL Handbook 217D indicates that the mean time between failures (MTBF) for electronic packages can be increased from 3000 hours to 7000 hours by reducing the electronic package temperature by 37°F through improved heat dissipation, as is available with carbon-carbon thermal planes.

Affordability

For space applications major drivers are affordability and weight. The Force Enhancement TPIPT identified a technology need to reduce the weight of the next generation MILSTAR from 10,000 lb to 4,000 lb to enable the system to be launched on a less expensive vehicle. Lightweight materials being developed in this thrust can provide up to one-half of the desired weight savings.

Other examples of weight savings include cost savings in satellite radiators and electronics. For satellites, Hughes has shown that carbon-carbon thermal doublers can result in life cycle cost (LCC) savings of $1,280,000 per vehicle over 5 years, and Loral has shown that carbon-carbon radiators can result in $948,000 per vehicle savings. Another study has shown a potential savings in electronic packaging weight of over 500 lb/spacecraft by the use of carbon-carbon resulting in $125M savings.

In aircraft, weight savings have a tremendous impact on life cycle operational costs. Composites can reduce weight by 35% but are often not used because of acquisition affordability. Thus techniques have been developed for self-directed processing that can reduce processing time up to 80% with associated cost savings (PRAM Report WL-TR-92-4085). These techniques have been demonstrated on an F-117A fuselage trailing edge and have been transitioned to SM-ALC for A-10 hardware. Impact from automated processing techniques on life cycle cost savings are presently being validated using the F-117A part. In addition, extensive research is underway to reduce manufacturing cost through knowledge based processes and cure models (F-22 application). Low cost processes also are being developed for filament wound isogrid ducts for the F119 engines. Goals of 30-50% acquisition cost reductions are being validated. Recent studies on fighter aircraft composite parts have been conducted to evaluate the potential of the 2000+ materials being developed, and a 50% weight savings has been calculated over the baseline part selected.

Another notable activity to improve affordability is in process modeling. By eliminating costly trial and error process development, lead time is reduced, providing higher quality products and generating higher yields. Process modeling, coupled material-process design, and intelligent process control significantly reduce life cycle costs of critical engine and airframe components.

Further LCC savings will be achieved through the insertion of ceramic matrix composite technology into current system critical components, such as F110 engine exhaust components and heat shields for F-117A and B-2 aircraft. Further savings will be achieved through the insertion of ceramic matrix composites into emerging system components, such as those of the F-22 engine exhaust system. Current ceramic matrix composite processing initiatives will further reduce future ceramic matrix composite costs. Also advanced intermetallic laminated coatings in a variety of applications are projected to yield vital turbine engine LCC savings.

Risk Reduction

Risk reduction for structural materials is achieved two ways. First, the materials are applied to existing secondary structures to gain confidence in producibility and learning curves and to gain operational experience before commitment to new systems. Second, the materials are made available well before technology freeze dates with an adequate database and understanding of how the materials act under expected application conditions. Failure analysis data allow designers to reduce structural risk through analysis.

Due to materials risk, the C-17 program choose to remove most of the aluminum-

lithium on the aircraft that was providing important weight savings. This thrust is reducing risks to the C-17 program by addressing these problems in a research and development program. When solutions are available at a low enough risk, recommendations will be made to re-employ the material.

Risk reduction is also achieved through process modeling and control. Casting, forging, and extrusion process models have been developed and are already in extensive use in the aerospace industry. Continued efforts will expand these applications and process studies will identify more efficient processing approaches.

Over the next 10 years, many opportunities for new materials involving system modifications are anticipated. After adequate databases have been developed, pursuit of new materials on these applications will proceed.

Engineering Tools

This thrust places heavy emphasis on engineering tools to allow system designers to intelligently and quickly incorporate these technologies. Tools being developed include:

- Design guide for use of materials
- Engineering databases
- Mechanical modeling codes
- Nonstructural materials MIL specifications
- Process modeling software
- Damage tolerance/life management models.

MAJOR ACCOMPLISHMENTS

This past year was one of unparalleled accomplishments within the Materials and Processes Technology Area. Just a very few of these are highlighted below:

- Baselined F119 engine production of actuator rods using titanium metal matrix composite with silicon carbide (SiC) fiber which saves 13.6 lb over stainless steel.
- Completed B-1 pump test of fire resistant hydraulic fluid MIL-H-87257 and received approved for flight test. Successful flight test of MIL-H-87257 was completed for the KC-135. Projected savings at $20M/year.
- Demonstrated processing techniques for carbon-carbon that reduced scrap 80%, and processing time 50%.
- Received approval for hydrolytically stable coolant MIL-C-87252 that requires less maintenance and costs less. MIL-C-87252 costs $9.40/gallon and replaces $400/gallon coolant. Has been selected for field conversion of LANTIRN and was selected as F-22 radar baseline coolant. Savings are estimated at over $20M/year.
- Received approval for cruise missile F107 engine conversion to MIL-G-XXXX grease that is water resistant, can withstand higher loads, and doubles mean time between overhaul. Estimated to save $5M/year.
- Conducted brassboard tests on carbon-carbon thermal planes that are 30% lighter than aluminum, 4x stiffer, and reduce chip temperatures by 60% which will double the reliability of advanced electronics. Life cycle cost savings for the F-15 fleet alone is projected at $12M/year.
- Transitioned inorganic matrix composite antenna window material technology to Extended Range Interceptor (ERINT) to improve all weather capability.
- Flight proven ceramic matrix composite window material and transferred technology to Navy's Trident RVs. Window absorbs 80% less moisture with an equivalent improvement in dielectric stability.
- Demonstrated the use of p-phenylene benzobisoxazole (PBO) fibers in a ballistic jacket for pressure vessels, representative of gas containers on satellites for attitude adjusters, which increased burst pressure resistance 95% over Kevlar.
- Developed new composite radome and antenna window material that is 20% lighter, more durable and less expensive for missiles and RVs.
- Developed a process to produce thick-walled ceramics for structural applications such as aircraft engines and rocket motors with equal or higher quality than conventional methods. New method takes weeks instead of months and lowers cost 80%, from $25,000 to $5,000 per rocket thruster.
- Solved recurring heat damage problem on the F-117A through the transition of a high temperature organic matrix composite, AFR700B, to SM-ALC. Material improved aircraft's performance while maintaining its low observable profile.

CHANGES FROM LAST YEAR

The Life Management of Aging Systems and Space SEAs have had the most impact on Thrust 1. These new efforts include:

- Investigating organic matrix composite material performance in a combined space thermal and structural loading environment.
- Development of M&P for advanced liquid and solid engines for Integrated High Performance Rocket Propulsion Technology (IHPRPT), Enhanced Expendable Launch Vehicle (EELV) and Reusable Launch Vehicles (RLV).
- Development of sealants to reduce the signature returned from aircraft seams which have lower manpower and skill level requirements.
- Analytically modeling composite patch repair methods to determine stress and predict failure modes in both the cracked metal substructure and composite laminate.
- Assessment of environmental behavior and durability of field and depot repair methodologies for damaged ceramic matrix composites in gas turbine engine exhausts.
- Development of methodologies to use microthin thermal protective coatings on turbine engine rotating components.

MILESTONES

- Lightweight battery cases in 1996.
- Environmentally acceptable corrosion inhibiting primer and aircraft thermal control coating (TCC) by 1996.
- Develop ceramic matrix composite processing model by 1996 to lower cost and improve reliability and maintainability.
- Develop efficient jointing and attachment methods for carbon-carbon by 1997.
- Joint flight and ground test of advanced RV materials with Phillips Laboratory in 1996.
- Develop net-shape process for carbon-carbon that reduces scrap 50% by 1997.
- Develop a comprehensive guide for optimal application of fast and low cost composite patches for aircraft by 1998.
- A new composite patch curing heating blanket system that will cure faster, at high temperatures, more uniformly, and produces a higher quality patch/bond by 1998.
- Provide environmentally compliant high performance powder based paints by 1998.
- Demonstrate affordable structural polymeric matrix composite materials that meet spacecraft thermal requirements by 1998.
- Fabricate lightweight (-30%), dimensionally stable materials for space surveillance and space systems by 1998 (carbon-carbon and nonmetallic composites).
- Verify antenna window material transmission characteristics for advanced RVs by 1998 with flight demonstrations by 2000.
- Demo 30% weight and cost savings for selected aircraft and engine structures by 1999 (advanced nonmetallic composites).
- Space qualify thermal control coatings to enable lighterweight, longer life spacecraft radiators with improved reliability and performance by 1999.
- Scale-up and transition environmentally compliant LO aircraft paint by 1999.
- Field and depot level repair techniques for ceramic matrix composite engine exhaust components by 1999.
- Structural ceramics for Innovative High Performance Rocket Propulsion Technology (IHPRPT) initiative by 1999.
- Availability of materials (> 1700°F) for hypersonic vehicles by 2000 (C-C, titanium aluminides, and ceramics).
- Develop high temperature (-65°F to 1500°F) *solid* lubricants for propulsion bearings, fasteners, etc. by 2000.
- Advanced metallic materials by 2000 for improved performance, reliability and affordability of cryogenic rocket engines
- Develop and validate materials to allow propulsion thrust-to-weight improvements of 100% by 2003. This includes compressor materials capable of 1700°F and turbine materials capable of 2800°F (titanium aluminides, ceramics, and their matrix composites). Have identified retrofit applications for selected materials by 1998.
- Qualify wider *liquid* range and higher temperature (-65°F to 700°F) fluid and lubricant systems for propulsion, hydraulic, and cooling subsystems by 2003.
- Demonstrate shape stable retention of guided RV materials for nosetips, leading edges, and antenna windows by 2003.

Thrust 2: Materials And Processes For Electronics, Optics And Survivability

The overall objectives of this thrust are to provide new electronic materials and material processes for:

1) Electronic, optical, and electro-optic devices and subsystems for aircraft, missile, and space systems
2) Survivability of aircrews, sensors, aircraft, and space systems.

As we saw in Desert Storm, advancements in electronics (radar, infrared (IR) detectors, communications, and their associated computation systems) have revolutionized warfare and provided the U.S. with an important war fighting advantage. This technology area has helped provide many of the materials utilized in these systems and continues the development of many breakthrough technologies. Advancements in gallium arsenide (GaAs) will reduce cost and improve reliability of advanced X-Band and Space Based Radars. Indium phosphide (InP) materials being developed are the next generation of materials for fighter radar and space based communication and also can be used for photonic as well as electronic applications. Silicon carbide (SiC) based electronics not only can provide much higher temperature capabilities but also higher power capability. Nonlinear optical (NLO) materials such as zinc germanium phosphide ($ZnGeP_2$) will be utilized in IR countermeasures (CM) with other materials used for electro-optic (E-O) and IR countermeasures and for remote sensing of chemical and biological contaminants. Several materials (yttria, zirconia, polycrystalline diamond [PCD], zinc sulfide [ZnS], and zinc selenide [ZnSe]) will provide improved sensor domes critical for stealth/night operation for LANTIRN, Maverick, and other current and future systems. The final electronics area involves high temperature superconducting (HTS) materials such as yttrium barium copper oxide (YBCO) and thallium barium calcium copper oxide (TBCCO). These materials will provide tremendous improvements for IR Focal Plane Array (FPA) Processors, digital microwave receivers, and advanced radar and communication circuits.

In the area of laser protection, near-term concern is for low power, fixed wavelength lasers which are now commercially available of intensity high enough to blind sensors and aircrews. Developments by the Materials and Processing (M&P) Technology Area now provides daytime protection capability for personnel and day/night protection for sensors against a limited number of these lasers. M&P are now being developed for nighttime personnel protection and enhanced sensor protection against multiple wavelength. But lasers are under development in which the laser frequency will be tunable. No capability presently exists for broad band protection from these lasers. In addition, future high power Directed Energy Weapons (DEW) will be able to structurally damage aircraft, missiles and spacecraft, and these areas are being worked by the M&P Technology Area. This area is coordinated with the other services through the Joint Directors of Laboratory electromagnetic protection; electrical, magnetic and optical; and advanced processing materials subpanels.

USER NEEDS

Thrust 2 is developing technologies that directly support needs of the Air to Surface, Counterair, Special Operations, Mobility, Missile Defense, Force Enhancement, and Information Warfare Technology Planning Integrated Product Teams (TPIPTs). (Information Warfare includes reconnaissance/ intelligence, strategic air defense, theater battle management, weather, and modeling and simulation TPIPTs.) Similar Mission Area Plan (MAP) deficiencies supported are for the Close Air Support, Strategic Attack, Counterair, the Air Force Special Operations Roadmap, Provide Mobility in Denied Territory, Combat Delivery, Electronic Combat, Rescue, Missile Warning, Ballistic Missile Warning, Military Satellite Communications (MILSATCOM), and Counterspace. A roadmap for Thrust 2 is presented in Figure 7 and an illustration of the correlation between Thrust 2 key technologies by the TPIPTs and MAPs is presented in Figure 8.

The largest number of identified user needs for Thrust 2 are for mid-term computing, communication navigation and datalink devices as well as offensive and defensive sensors. From review of the MAPs and TPIPTs,

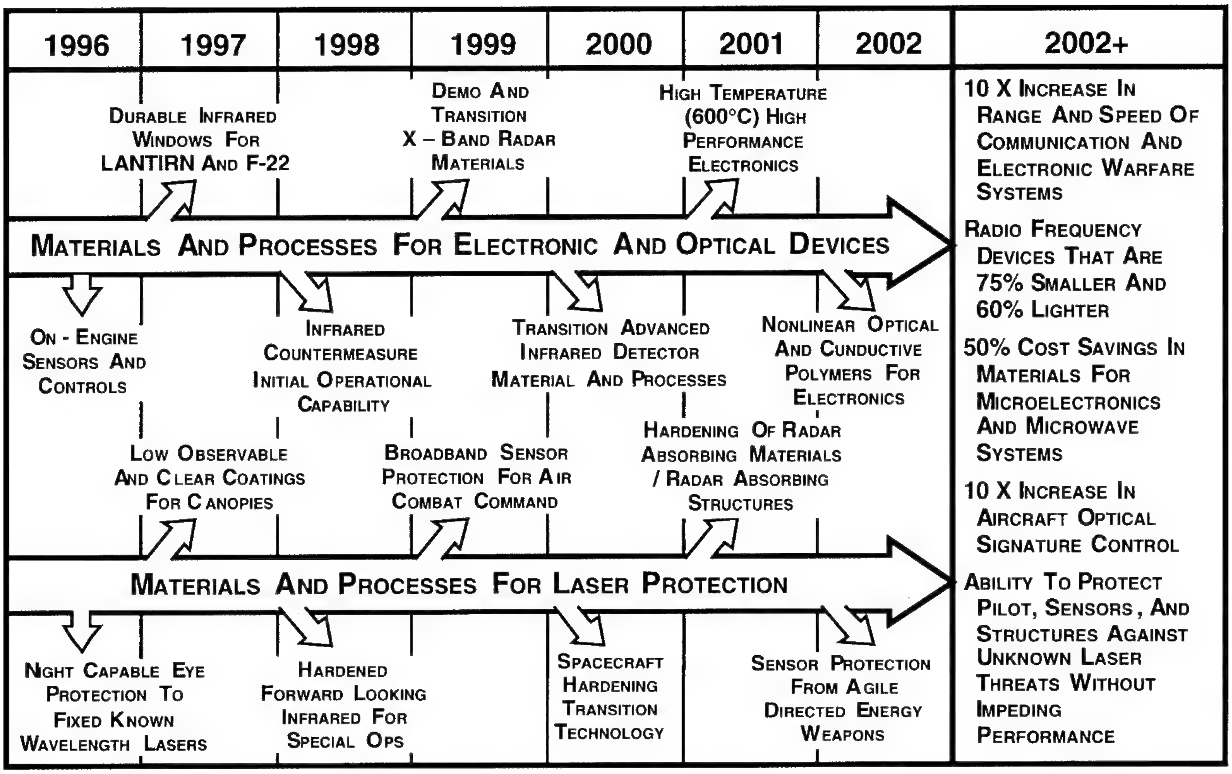


Figure 7: Thrust 2 - Materials and Processes for Electronics, Optics, and Survivability

it should be noted that these needs have the broadest application of technologies being developed by the M&P Technology Area. These broadly based needs are directly impacted by semiconducting, NLO and superconducting materials (GaAs, SiC, InP, semi-organic polymers, YBCO, and TBCCO). There are fewer but a significant number of user needs supported by Thrust 2 for countermeasures and laser hardening.

The user needs which require enhanced **computing, communication, navigation and datalink** capabilities cover terrain following; offboard datalinkage; improved seeker range and sensitivity; integrated optics; optical interconnects for computing and communication; enhanced weapon support; and secure, jam resistant communications with low probability of intercept for local, beyond line-of-sight and global capabilities. These needs are for electronic and avionic components such as data processors, communication systems, Global Positioning Satellite (GPS), mass storage devices, satellite beacons, Analog-to-Digital (A/D) converter amplifiers, and graphic displays. Higher throughput (speed), temperature, and/or power (micro)electronic and microwave devices are to be developed that are lower in cost, smaller, less complex, lighter, and more reliable. Over 80 TPIPT concepts having over 140 related Thrust 2 technology needs were identified from the Air-to-Surface, Counter Air, Special Operations, Missile Defense, Information Warfare, Strategic Defense, Force Enhancement, Counterspace, Mobility, Electronic Combat, and Space Support TPIPTs. The MAPs with computing, communication, navigation and datalink deficiencies are Combat Delivery, Close Air Support, Strategic Attack, Counterair, Air Force Special Operational Command (AFSOC) Roadmap, Provide Mobility in Denied Territory, Missile Warning, Ballistic Missile Defense, Theater Defense, Surveillance and Reconnaissance, Strategic Air Defense, MILSATCOM, Nuclear Deterrence, Counterspace, Space Surveillance, Air Base Defense, Electronic Combat, Rescue, and Satellite Control.

Ultraviolet (UV), visible, E-O, laser, and IR sensors for satellites, missile seekers, aircraft warning receivers and aircraft offensive avionic suites are dependent on electrical and optical M&P being developed by Thrust 2. Specific TPIPT technology needs are for dual-mode, multi-mode, multi-spectral (all weather,

Key Technology Needs	M&P For Computing, Communication Navigation and Datalinks	M&P For Offensive and Defensive Sensors	M&P For Countermeasures Defensive Systems	M&P For DEW Sensor Protection	M&P For Electromagnetic Windows and Canopies	M&P For Personnel Laser Protection	M&P For Laser (Threat) Simulation	M&P For Structural Laser Protection
Air-To-Surface TPIPT								
Counterair TPIPT								
Special Operations TPIPT								
Airbase Operability TPIPT								
Mobility TPIPT								
Electronic Combat TPIPT								
Missile Defense TPIPT								
Force Enhancement TPIPT								
Strategic Defense TPIPT								
Space Control TPIPT								
Space Forces Support TPIPT								
Information Warfare TPIPT (Includes Reconnaissance / Intelligence, Strategic Air Defense, Theater Battle Management, Weather and Modeling & Simulation TPIPTs)								
Close Air Support MAP								
Strategic Attack / Air Interdiction MAP								
Counter Air MAP								
Air Force Special Operational Command Roadmap MAP								
Provide Mobility In Denied Territory MAP								
Airbase Defense MAP								
Air Mobility Command Master Plan MAP								
Combat Delivery MAP								
Electronic Combat MAP								
Rescue MAP								
Missile Warning MAP								
Ballistic Missile Defense MAP								
Theater Defense MAP								
Military Satellite Communications MAP								
Spaced-Based Weather and Environmental Warning MAP								
Spaced-Based Navigation MAP								
AFSPC Nuclear Deterrence MAP								
ACC Nuclear Deterrence MAP								
Counterspace MAP								
Space Surveillance MAP								
Satellite Control MAP								
Surveillance and Reconnaissance MAP								
Strategic Air Defense MAP								

Figure 8: Thrust 2 Key Technologies For MAPs & TPIPTs

through obscurants, color, like eye vision), 4-pi coverage, real-time target identification, low-cost, active laser radar (LADAR) target recognition integrated with improved Forward Looking IR (FLIR), increased sensitivity at longer range with wider angle (spatial) resolution, single aperture / multipurpose, miniaturization, detection methods using new phenomena, low cost, lightweight, less power input, asynchronous, ability to function at high mach, and modular Synthetic Aperture Radar (SAR). Similar **offensive and defensive sensor** technology from Thrust 2 is needed for: Air Base Operability, Counter Air, Combat Delivery, Close Air Support, Electronic Combat, Strategic Attack, Strategic Air Defense, Surveillance & Reconnaissance, Theater Missile Defense, Special Operations, Space-Based Weather & Environmental Monitoring, Missile Warning, Ballistic Missile Defense, Nuclear Deterrence, Counterspace, Rescue, and Space Surveillance MAPs.

Advanced optical concepts are being developed to provide **sensor DEW protection**. Specific TPIPT technology needs are for low cost, lightweight protection of aircraft, satellite and missile sensors from fixed / agile broadband laser threats. The performance criteria are for hardening concepts that not only protect the sensor but also allow the system the ability to complete its mission while under engagement. These hardening concepts can be applied to laser warning, FLASER, EO/IR & Radio Frequency (RF) sensors, FLIR and LADAR for several

concepts in the Air-to-Surface, Counterair, Mobility, Special Operations, Electronic Combat, Missile Defense, Force Enhancement, and Space Control TPIPTs. MAPs that have DEW sensor protection deficiencies identified are Counterair, Close Air Support, Nuclear Deterrence, Strategic Attack, Provide Mobility In Denied Territory, Special Operations, Counterspace and Air Mobility.

The third highest number of identified TPIPT needs and MAP deficiencies being addressed by Thrust 2 are related to **countermeasure/defensive systems**. $ZnGeP_2$, semiorganics, E-O polymers, and ferroelectric M&P are being developed to enhance CM capabilities. The performance criteria desired are for an ability to jam enemy's systems and the ability to operate while being jammed. In general, the TPIPT technology needs are for miniaturization and higher energy conversion over a wider area of coverage at longer ranges. Higher energy conversion relates to the desire for lower input power requirements while increasing output power which will lower the overall systems weight and complexity. The MAPs with countermeasure/defensive systems deficiencies are Counterair, Electronic Combat, Rescue, Provide Mobility In Denied Territory, Combat Delivery, Close Air Support, Strategic Attack, Surveillance & Reconnaissance, and Special Operations.

ZnS, ZnSe, GaAs, Germanium, Yttria, Zirconia, and transparent polymers are being developed for **electromagnetic windows and canopies**. The primary performance criteria are for longer life/enhanced durability to environmental exposure and for infrared Search and Track (IRST) at supersonic speeds. TPIPT transparencies, (long wave IR [LWIR]) windows, sensor domes, radomes and cockpit canopies needs are for increased life by reducing rain / dust erosion, canopies with electrochromatic variable transmissivity, and high mach / supersonic / hypersonic flight with sensors operating such as IRST which is critical for night/stealth operations. MAPs with electromagnetic window and canopy deficiencies are Combat Delivery, Close Air Support, Theater Defense, Special Operations, Air Base Operability and Counterspace.

Day/night protection of pilot and aircrew eyes from fixed, agile and broadband threat lasers and laser range finders are dependent upon the development of new M&P. Goggles, visors, heads-up displays, night vision goggles, and helmet mounted displays need hardening/protection with minimal impact on performance (including minimal weight). Identified TPIPTs with **personnel laser protection** requirements are Counterair, Air-to-Surface, Special Operations, Combat Search and Rescue, Electronic Combat, and Airbase Operability. The MAPs with similar identified deficiencies are Counterair, Close Air Support, Rescue, Strategic Attack, AFSOC Roadmap, Provide Mobility In Denied Territory and Air Mobility Master Plan.

Besides protecting sensors and eyes from DEWs are needs for **structural DEW hardening**. The applications include load bearing structures, fuel tanks, munitions, solar arrays, antennas, laser crosslinks (X-links), radiators, multilayer insulation and radar absorbing materials / radar absorbing structures (RAM / RAS) for aircraft, missiles and spacecraft. In order to quantify the susceptibility levels of these structural components, a comprehensive database of material susceptibilities is being complied. Protective materials and coatings are being developed for critical components such as aircraft canopies and windows. Structural laser protection requirements were found in the Counterair, Mobility, and Space Control TPIPTs and Counterspace MAP.

To develop protection for sensors, personnel and structures from lasers, realistic **laser threat simulation** must be conducted. The M&P Technology Area conducts accurate, repeatable DEW simulation similar to future threats to gather survivability/lethality data on weapon effectiveness. This includes development of beam focusing, adaptive optics, and precise pointing/tracking control of beam spot on the target. The goal is to determine the survivability of U.S. systems and the lethality of our future DEWs against enemy systems. DEW simulation needs were found in the Counterair, Air-to-Surface, Air Base Defense, Missile Defense, and Counterspace TPIPTs and the Counterspace and AFSOC MAPs.

GOALS

Materials for radar systems, microwave and micro-electronic equipment, IR detectors, photonic devices, and optical processors are being developed to meet mission area

requirements in target acquisition, guidance, communication, electronic warfare, and data processing. Specific goals include:

- Transition IR window coatings that have >200% improvement in rain and dust durability. Then, develop a more affordable dome that is inherently more durable for tactical missiles followed by development of aircraft IR windows that are survivable at supersonic speeds to allow the F-22 to use passive IR sensors at supersonic speeds (critical to stealth / night operations).
- 10X increase in microwave device power without increasing device size through insertion of SiC technology.
- High performance IR detector for space to replace / augment ground based systems.
- 50% cost savings in materials for microwave and microelectronics systems through increased production yield.
- IR detector materials with sufficient resolution and range to replace and augment radar (nonstealth / acquisition systems).
- HTS materials for radar and communication systems to increase dynamic range 10-100X while being 10X smaller and lighter.
- Wavelength tunable IR laser with 10X power output using improved materials.
- E-O polymers with high thermal stability and large E-O coefficient to enable a 10X improvement in processing and computing.

Overlying the above goals is a strategy to address cost and availability of electronic and optical materials to fulfill system needs.

Laser hardening goals include:

- Laser protective eye wear for aircrews flying day and night missions.
- Laser hardened tactical and strategic electro-optic sensors.
- Provide structural protection for aircraft, missile, and spacecraft critical components.

The goal is to provide protection for aircrews, strategic/tactical sensors and weapon systems without disruption of their primary mission. Eyes and E-O sensors are sensitive to glare and jamming at power levels many orders of magnitude below damage levels. This necessitates the development of protection technologies with very high dynamic ranges or the combination of multiple protection devices. Protection goals will be achieved in incremental steps from progressing from fixed wavelength protection to tunable laser protection technologies.

Operational Capability Impact

As Desert Storm demonstrated, the two most significant advances in warfare technology have been in signature control and electronics. Yet the potential in electronics, optics, and electro-optics has hardly been tapped. This thrust will lead the way to revolutionary advancement over the next 5-10 years. One of the problems that surfaced during Desert Storm was the erosion of optical windows. The solution being developed under Thrust 2 focuses development and application of PCD, oxide, and polymeric coatings for ZnS, ZnSe and GaAs substitutes for IR windows / domes. This technology will also provide > 200% increase in lifetime over existing materials to extend service life and reduce downtime.

Commercially available, low power lasers can spoof, jam and even damage E-O sensors. Similarly, these lasers can temporarily and permanently blind aircrews at extended ranges. The ability to provide operational protection against selected fixed known wavelength lasers has been demonstrated for both aircrews and IR sensors. Multiple wavelength laser protection has been demonstrated for aircrews only for high illumination levels (daytime) where sun visors would normally be worn. IR sensor protection is typically limited to a single wavelength because of the excessive throughput loss and resulting performance impact on the sensor. Near term goals are to provide multiple wavelength protection for aircrews at night and multiple wavelength protection for IR sensors. The longer range objective is to protect both aircrews and sensors from unknown / agile wavelength lasers. These technologies are operational capability enablers, since loss of eyesight or a blinded sensor can defeat a mission.

Supportability

InP and HTS thin films of YBCO and TBCCO materials are being developed for identified needs concerning advanced aircraft high resolution radar and RF communication components. Also $ZnGeP_2$ materials are being developed to make possible laser based integrated IR countermeasure (IRCM) systems which will meet identified needs for advanced countermeasure techniques.

Sand erosion was a severe problem for aircraft and missile IR windows during Desert Storm, and both sand and rain erosion are problems for IR windows and domes. Survivability of IR domes and windows at supersonic speeds has generated even greater requirements that are being addressed for the F-22 and future systems applications. Approximately 70 IR windows are damaged and need replaced each year for LANTIRN. This is only one of many systems that uses IR windows or domes and other M&P Technical Area efforts include working with Ogden Air Logistic Center (OO-ALC) to suppress dust erosion of the Maverick missile IR dome.

Supportability personnel attend program reviews and assist in evaluation of proposals.

All materials are tested to the appropriate supportability requirements:

- Personnel protection:
  MIL-V-22272 (abrasion),
  MIL-V-43511 (optical performance),
  MIL-STD-662D (ballistic safety),
  MIL-H-87174 (windblast safety), and
  MIL-STD-810 (environmental durability)
- Sensors: MIL-C-48497A (environmental durability), and
- Transparencies: MIL-F-48616 (abrasion).

Affordability

For microwave and microelectronics, two steps are taken to provide cost savings:

- Process development to produce larger wafers with improved production yield.
- In situ process modeling to significantly improve material quality and yield (a 100% increase is expected in production yield for these materials over existing production systems, which will result at least a 50% cost savings in electronic wafers).

For survivability, M&P are being developed under Thrust 2 to prevent costly systems loss, mission denial or damage due to laser irradiation at the lowest cost with minimal or no performance impact. For MAP and TPIPTs identified M&P are being developed to protect equipment and personnel (sensors and eyes). In retrofitting current systems, Thrust 2 works closely with Systems Project Offices (SPOs), such as LANTIRN and AGM-130, to provide materials with optimum balance of maximum laser protection and minimal cost impact due to materials and costs.

Risk Reduction

Thrust 2 reduces integration risk by coordinating with Wright Laboratory Electronics, Avionics, and ManTech Directorates as well as the Electromagnetic Materials Technology Division and Antennas and Components Division under Rome Laboratory's Electromagnetic and Reliability Directorate. Adequate funding is provided and supplemented with Advanced Research Projects Office and Air Force Office of Scientific Research funding. Milestones are scheduled with the Directorates to meet customer needs. In the IR window/dome area, a development program is coordinated with the Avionics Directorate and the F-22 SPO to assure timely availability. For space, technologies are coordinated/planned with the Space and Missile Systems Center and Phillips Laboratory. Besides coordinating technology insertion, the M&P Technology Area reduces risk through multiple technical approaches such as for survivability with the development of rugate filters and holographic devices.

Engineering Tools

This thrust has developed several databases as aids for implementing laser hardening concepts. These include optical material damage thresholds, amount of hardening required for sensors based upon the optical gain of the system and materials, susceptibility of the sensor to jamming both on- and off-axis, and damage/subdamage thresholds of structural materials. Both LANTIRN and AGM-130 SPOs have benefited from these databases. These databases will greatly assist in future systems development and modifications to meet survivability requirements.

Programs are addressing materials physics/ behavior, modeling (behavior and growth) and processing to provide tools for the designer.

MAJOR ACCOMPLISHMENTS

- Developed a new optical filter technology, Rugates, that offers unlimited design freedom for the manufacture of thin-film filters. Will replace conventional optical coatings and improve sensor performance with a significant reduction in manufacturing cost.
- Jointly developed with industry an improved NLO crystal material to extend laser

transmission range 15% with 10X less resistivity and has applications in communication, CM, laser radar, and medical lasers.

- Ultrapure polycrystalline silicon as starting material for single crystal silicon IR sensors and semiconductor devices was made in commercial quantities. This will improve sensor sensitivity 25%, allow higher power transistors, and higher density microchips.
- Developed new single step in situ process for making HTS thin films which has superior properties and is enabling very high speed computers, improved electronics, and improved microwave devices.
- Produced reliable, large single crystals of silicon carbide that will enable rugged, radiation tolerant semiconductors operating at to 600°C for higher power radars and other defense and commercial applications.
- Developed improved erosion resistant coatings for ZnS and ZnSe IR sensor windows to double present rain erosion resistance. Result is longer mean time between replacement of IR windows which will save the Air Force $5 million in life cycle costs for the Maverick, LANTIRN and F-22 IR sensor systems.
- Proved that large, high optical quality ZnGeP2 E-O crystals for improved IRCM can be produced. Another benefit is that crystals can be used in determination of air pollutants and their sources.
- Develop technique for measuring nonlinear absorption of light energy that is up to 100,000 times more sensitive than current methods. Technique was needed to determine optical properties for laser hardening, optical communication, image processing, and fiber-optic communication.
- Provided quick reaction support to Special Operational units in the development and fabrication of a low cost filter that allows aircrews to perform tasks in the cockpit under minimal lighting conditions.
- Demonstrated FLIR damage protection with an IR optical limiter and rugate filter in laboratory and field tests.
- Fabricated prototype holographic spectacles for night fixed wavelength laser eye protection. This technique will be scaled-up to achieve multiple wavelength aircrew eye protection for night operations.

CHANGES FROM LAST YEAR

The Space, Life Management of Aging Systems, and Pollution Prevention SEAs have all had a significant impact on Thrust 2 and some of the new efforts involve:

- Lower cost and more reliable LWIR space-based detectors
- Form and function replacement of aging electronic and avionic subsystems with added functionality and reliability
- Fabrication techniques for short-run production replacement of avionic components
- Molecular beam epitaxy fabrication of electronics using less toxic reactants.

MILESTONES

- An E-O polymer with high thermal stability and large E-O coefficient will be achievable for high speed avionics by 1996.
- InP substrates - providing 50% improvements in operating frequencies and power handling capabilities over GaAs substrates - will be grown to 3-inch single crystal diameters with very low defects and a 2X increase in yield by 1996.
- Coatings with a 3X durability improvement for IR windows transitioned to the F-22 for supersonic IRST in 1997.
- Multilayer HTS technology for interconnects and Josephson Junctions (JJ arrays) will be optimized by 1997.
- A series of milestones will lead to personnel and sensor protection from lasers through 2005. These milestones include:
  - Night capable aircrew eye protection for fixed wavelength lasers by 1996
  - Broadband sensor hardening for pulsed lasers by 1996
  - Laser and environmentally hardened aircraft canopy coating by 1997
  - Statistical day-only aircrew eye protection for agile wavelength lasers by 1998
  - Preliminary day-only aircrew eye protection for agile wavelength lasers by 2000.
- Develop high yield, cost effective, high performance mercury cadmium telluride (HgCdTe, MCT) semi-conducting materials that are responsive across the IR spectrum for space sensors by 1999.

Thrust 3: Materials And Processes For Systems And Operational Support

The overall objectives of this thrust are to:

- Establish nondestructive evaluation (NDE)
  - to detect and monitor service-initiated damage or deterioration
  - to assure optimum quality in the production of Air Force systems.
- Develop materials and processes (M&P) to minimize hazardous / toxic (HazTox) materials in repair and maintenance processes.
- Provide materials and processes support across all Air Force mission areas
  - quick reaction support (i.e. failure analysis) to material problems in the operation commands and maintenance facilities
  - technical support to System Program Offices through collocated engineers
  - data on new materials and processes for transitioning of technology.

Customers supported by this thrust include:

- Systems Program Offices (SPOs)
- Air Logistics Centers (ALCs)
- Major Commands (MAJCOMs)
- Office of Special Investigation (OSI)
- Accident Investigation Boards
- Other Air Force Laboratories
- Federal Aviation Administration (FAA)
- Air Force Contractors and others.

During a typical year, approximately 90 structural analyses, 60 electrical failure analyses, 19 material property analyses, as well as many other support activities, such as corrosion prevention support, are provided to these customers. Typical activities over the past year included investigating the following:

- Commercial aviation material suppliers
- Coast Guard C-130 paint peeling
- HH-65A fuel pumps
- F-16 landing gear failure - accident
- T-41 oil pump failure - accident
- B-1B cooling tube welding failure
- F-15 and KC-135 wheel tie bolt nuts
- C-17 titanium hydraulic tubing
- C-141 weep holes
- F-117 first stage engine blades
- Air Force Academy parachute cables
- Comfort liners for pilot helmets.

This area is coordinated with the other services through the Joint Directors of Laboratory Technology Panel for Advanced Materials (JDL/TPAM) NDE technology, advanced processing, and materials transition / technology demonstration subpanels.

USER NEEDS

Thrust 3 develops the technologies that directly support needs of the Environmental Safety and Occupational Health and Mobility Technology Planning Integrated Product Teams (TPIPTs). Similar Mission Area Plan (MAPs) deficiencies supported are for the Combat Delivery, Air Force Special Operational Command (AFSOC) Roadmap, and Air Mobility Command (AMC) Master Plan MAPs. However, along with the MAPs and TPIPTs, there are a significant number of related technology needs from the center technology council (CTC) in which Thrust 3 is developing solutions or can play a major role in resolving. These CTC technology needs are from Air Force's test and engineering centers and ALCs. A roadmap for Thrust 3 is presented in Figure 9 and an illustration of the correlation between key technologies developed by Thrust 3 for all TPIPTs, MAPs, and CTCs is presented in Figure 10. The largest number of identified user needs for Thrust 3 technologies are for near-term pollution prevention, systems support, and NDE. MAPs do not directly address support issues and thus no affordability, manufacturing, or fabrication deficiencies were identified.

As stated the TPIPTs and MAPs do not adequately identify aging systems requirements. Most of the related technology needs for systems support and NDE come from the CTCs. Ways of extending lifetime for the current Air Force fleet of aircraft, spacecraft, and missiles has become an important part of the Air Force and Thrust 3. The combined effort of systems support and NDE makes up the majority of the M&P Technology Area activities under the Life Management of Aging Systems Strategic Emphasis Area (SEA). In general the Life Management of Aging Systems SEA covers a broad spectrum or technologies dealing with using systems beyond their designed service life, corrosion, fatigue, and life prediction.

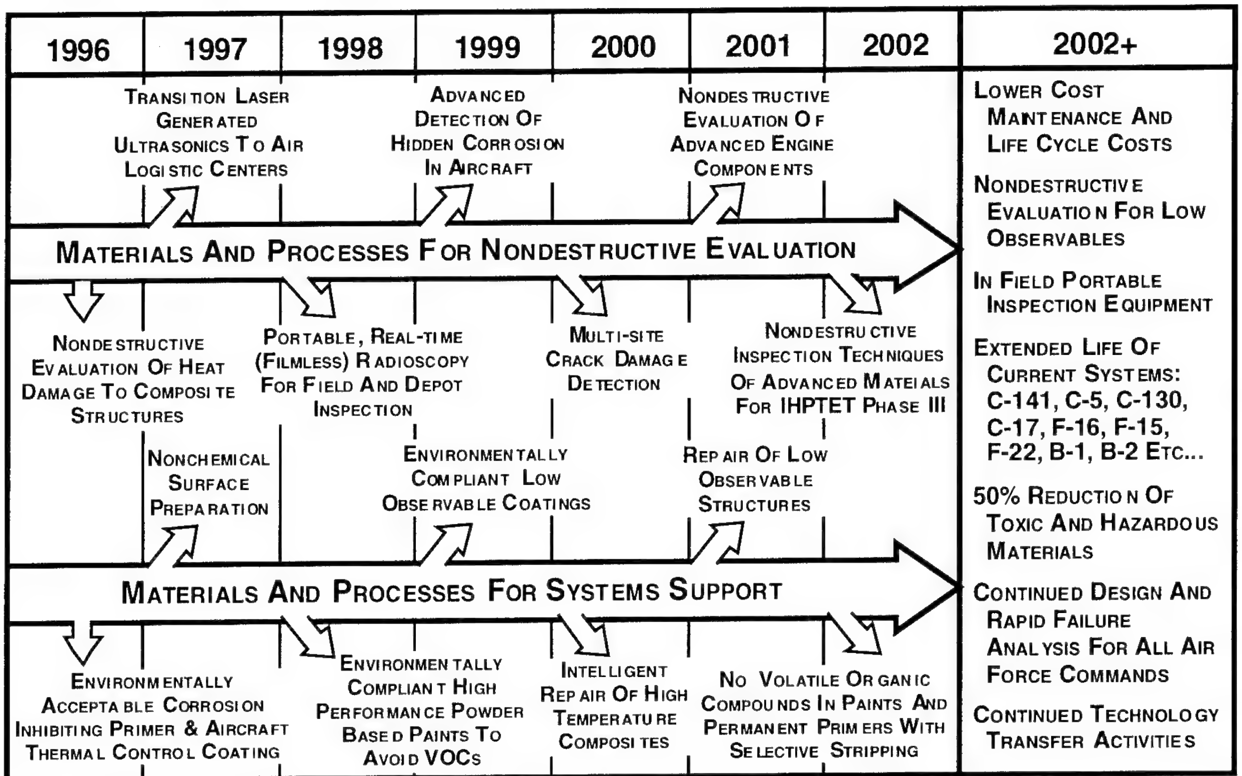


Figure 9: Thrust 3 - Materials and Processes for Systems and Operational Support

Two of the primary concerns in aging systems are the **nondestructive evaluation** of hidden corrosion and multi-site crack damage. Thrust 3 has programs addressing both of these key user needs. In developing advanced materials, it is also critical that inspection techniques to monitor a structures degradation and internal damage be developed to promote usage of materials and to avoid costly removal and replacement prematurely. The TPIPTs for which NDE technology is being developed are Counterair, Air-to-Surface, Mobility, and Strategic Defense. The MAPs in which Thrust 3 NDE efforts can solve or play a major role are Counterair, Strategic Attack, Special Operations Roadmap, Air Mobility Master Plan, and Spacelift.

The M&P Technology Area **systems support** directly interfaces with user organizations (SPOs, MAJCOMs, ALCs) to provide the basic tools for material selection, design, processing, battle damage repair, and failure analysis. Also, Thrust 3 has established extensive databases on materials and their performance under service conditions, including life prediction. These databases are critical when predictions fail, designers underestimate load conditions, etc. Then failure analysis and recommended solutions are needed, often to prevent fleet grounding. Thus a payoff from this thrust is to provide failure analysis support in a timely manner. The Air Force does not plan for failures, but the M&P Technology Area is there when needed. With the drop in new system procurements over the next 10 years, the age of systems will increase and associated maintenance problems will grow. Thus, this Thrust 3 will continue to grow in importance. The TPIPTs with system support technology needs that are being developed by Thrust 3 are Air-to-Surface, Mobility, Special Operations, Airbase Operability, Missile Defense, and Space Support. The MAPs where system support technologies are identified include Counter Air, Surveillance & Reconnaissance, Combat Delivery. Strategic Attack, Spacelift, Nuclear Deterrence and Special Operations.

Thrust 3 **pollution prevention** efforts are to reduce HazTox materials during processing, fabrication, and maintenance – neither waste disposal nor remediation. Environmentally compliant M&P is probably the fastest growing user need, and Thrust 3 has the Air Force responsibility to develop new M&P that minimizes or eliminates HazTox wastes. The

Key Technology Needs	M&P For Pollution Prevention	M&P For Systems Support	M&P For Nondestructive Inspection / Evaluation
CTC Technology Needs		■	■
Air-To-Surface TPIPT	■	■	■
Counterair TPIPT			■
Special Operations TPIPT		■	
Airbase Operability TPIPT	■	■	
Mobility TPIPT	■	■	■
Missile Defense TPIPT		■	
Force Enhancement TPIPT	■		
Strategic Defense TPIPT	■		■
Space Forces Support TPIPT		■	
Environmental, Safety & Occupational Health TPIPT	■		
Strategic Attack / Air Interdiction MAP		■	■
Counter Air MAP	■	■	■
Air Force Special Operational Command Roadmap MAP		■	■
Air Mobility Command Master Plan MAP	■		■
Combat Delivery MAP		■	
AETC Accession MAP	■		
AETC Education MAP	■		
AETC Flying Training MAP	■		
ACC Nuclear Deterrence MAP		■	
Spacelift MAP		■	■
Surveillance and Reconnaissance MAP		■	

Figure 10: Thrust 3 Key Technologies For MAPs & TPIPTs

pollution prevention needs in which Thrust 3 is working are Ozone Depleting Chemicals (ODCs) free fire suppressants and refrigerants (Halon & Chloro Floro Compounds [CFC] replacements), Volatile Organic Compounds (VOCs) free cleaning & degreasing materials and techniques, processing methods to avoid metal bearing waste, low emission protective coatings, processes to avoid other air emissions, propellants, reduction/elimination of 17 chemicals targeted by the Environmental Protection Agency (EPA), and biodegradable chaff. The TPIPTs with pollution prevention needs being supported by Thrust 3 are Air-to-Surface, Mobility, Strategic Defense, Airbase, Force Enhancement and Environmental Safety & Occupational Health. The MAPs with pollution prevention deficiencies in which Thrust 3 is solving or can play a major role are Counterair, AMC Master Plan, and Air Education and Training Center's (AETC) Accession, Education, and Flying Training MAPs.

GOALS

Goals include:

- NDE techniques for hidden corrosion
- NDE techniques that can identify areas of multiple small cracks that together constitute structural integrity concerns
- Maintaining a quick reaction response of less than 72 hours to critical materials related problems in the field
- Ability to inspect low observable structures for electromagnetic integrity
- Continued collocated engineering support to major SPOs
- Reduction in HazTox materials used in Air Force operations by 50%
- 40X increase from 5 to 200 ft^2/hr in speed of inspecting large areas of composites
- Automated design of inspection processes for 10X time and cost savings.

Operational Capability Impact

Presently many Air Force operations are in danger of being shut down due to inability to meet environment / hazardous materials requirements. For example

Sacramento ALC (SM-ALC) has had to reduce corrosion inhibiting chromates to meet California environmental standards and has resulted in increased maintenance requirements. This thrust area is addressing material substitutions that will avoid future environmental liability; reduce adverse personnel health and safety; and avoid costs associated with handling, treatment, disposal, manifesting and management of hazardous materials and their waste streams.

Operational capability is also dramatically impacted by material failure analysis, which allows corrective actions to be taken thus avoiding fleet grounding and system down-time for repair. Nondestructive evaluation also allows defects to be found before failure and thus allow corrective action before a major problem occurs affecting operations.

Supportability

The primary emphasis of this thrust is supportability. Aging aircraft and new materials are dramatically impacting the supportability of Air Force systems. Aging systems increase the need to find hidden corrosion and multiple crack sites that result in material failures. These are three of the major tasks in this area. Accomplishments below highlight a couple of the 169 structural and electronic failure analysis activities conducted during the past year for operating commands and overhaul centers as well as many other support activities. Materials in new aircraft also bring new needs in inspection and repair. New aircraft with large areas of composites, such as wings, need economical inspection methods. This thrust will increase that inspection rate 40X that translate to a 95% reduction in inspection time. A third and growing area of support is developing materials and processes to eliminate hazardous materials at repair centers.

Affordability

Affordability in this area is strictly through life cycle cost savings in maintenance costs and in resolution of materials related failures in the field. As indicated above, efforts will improve inspection rate of composites by 40X. Examples of cost impact in failure analysis are highlighted in Accomplishments below. Cost effective repair processes, such as hot bonding and large area composite repairs are developed under this thrust.

Risk Reduction

Nondestructive evaluation techniques and repair methods work directly with the air logistics centers to resolve implementation issues and reduce execution risks. Also the development of extensive databases on new materials reduces risk in new systems. Understanding of process variables on properties and demonstration of reproducibility are being done for advanced materials. Materials are subjected to rigorous testing programs to assure that unforeseen material problems will not develop in service.

Engineering Tools

The M&P Technology Area is developing inspection equipment, procedures, and standards for inspection. Standards in types and sizes of potential defects are collected and made available to designers for determination of critical flaw size. This thrust is responsible for several handbooks: MIL-HDBK-5 on Damage Tolerance, Aerospace Structure Metals , and Structural Alloys. In the future, there will be an Electronic Failure Analysis Handbook and a Composite Failure Analysis Handbook. A specification developed on improved damage tolerance castings is now being used on F-16 and LANTIRN. Specifications developed for titanium castings are being used in the C-17 and is being considered for use in the F-22.

MAJOR ACCOMPLISHMENTS

- Analyzed and repaired wind tunnel fan blade cracking problem at Arnold Engineering Development Center (AEDC) which prevented 4 months of delays in the F-22 and F/A-18 programs saving the Air Force over $800,000.
- Solved a durability problem with bleed-air ducts on C-130 which avoided grounding of the aircraft and decreased unscheduled maintenance downtime.
- Developed a repair for defective weldments found in 740 solid rocket motors hangers saving the Air Force $1.5 million.
- Developed a composite patch repair process for over 100 C-141's which had fatigue cracks around the wing weep holes. Quickly returned the aircraft to operational status saving millions of dollars.

- Provided quick-reaction support to 16th (Gunships), 20th (PAVE LOW) and 55th (Blackhawk) Special Operations Squadrons and several U.S. Marine units with a critical need for aircrews to perform tasks in the cockpit under minimal lighting conditions during operations.
- Resolved F-22/F119 engine microcracking of alloy C electron beam welds of combustor resulting in $10.8M savings.
- Evaluated C-5 / TF39 engine fan blade cracking problem saving $300M.
- Completed failure analysis of cargo net hook assembles used in commercial and military applications.
- Tested environmentally acceptable corrosion inhibiting adhesive primers.
- Evaluated sealant adhesion to new high solids and water borne organic coatings.
- Conducted testing to qualify a new epoxy fuel tank coating for Peace Shield.
- Demonstrated F-16 composite patching of Air Force / Netherlands wing vent hole which saves $20,000 per aircraft.
- Evaluated room temperature storable prepregs for repair applications.
- Performed impact testing on C-17 honeycomb panels.

CHANGES FROM LAST YEAR

Both the Life Management of Aging Systems, and Pollution Prevention SEAs have all had a significant impact on Thrust 3. Some of the new efforts involve:

- Four new start pollution prevention projects were placed on contract to address high priority requirements. The four new starts cover 1) Solid State Metal Cleaning, 2) Atomic Oxygen Cleaning Process, 3) Laser Decomposition of Organo-Metallic Chrome and Nickel, and 4) Large Area Powder Base Priming and Coating.
- Designs for composite patch repairs and a patch repair handbook for depot engineers.
- Intelligent high temperature advanced composite and adhesively bonded repair system utilizing new heating blanket concepts to reduce temperature variations.
- Enhancement of the inspection methods, equipment and processes for use in the Retirement - For - Cause and Engine Structural Integrity Programs at San Antonio and Oklahoma City ALCs (SA-ALC and OC-ALC), respectively, to inspect all of the Air Force's gas turbine engine disks.
- Enhanced C-scan corrosion detection image analysis tools for OC-ALC.

MILESTONES

- Establish rapid, large area (200 ft^2/hr) aircraft composite inspection by 1996.
- Efficient corrosion NDI detection (increased productivity and reliability of NDI corrosion detection with decreased maintenance actions due to false calls) for C/KC-135 Service Life Extension Program (SLEP) by 1997.
- Faster nondestructive failure analysis of complex specimens using computer tomography by 1998.
- Develop a portable real-time (filmless) radioscopy system for aircraft inspection and battle damage assessment by 1998.
- Demonstrate a high resolution computed tomography inspection of solid rocket motorcase and bondlines by 1998.
- Establish environmentally compliant coating by 1998.
- Provide nonchemical surface preparations to eliminate hazardous materials by 1998.
- Distribute composite repair design guidelines by 1998.
- Develop new heating blanket system for composite patch curing that cures faster, heats more uniformly and produces higher quality patches / bonds by 1998.
- Identify a nonintrusive NDE technique for the detection of hidden corrosion in aircraft structures by 1999.
- Ability to conduct rapid, reliable laser guided ultrasonic inspection of composites and bonded structures by 1999.
- Demonstrate ability to detect hidden flaws and multisite cracks by 2000.
- Establish inspection techniques to assure structural and electromagnetic integrity of low observable materials by 2000.
- Demonstrate large area repair of composite structure by 2000.
- Continued 72-hour quick-action response to field/depot material related problems.

GLOSSARY

A/D – Analog to Digital

AEDC – Arnold Engineering Development Center

AETC – Air Education & Training Center

AF – Air Force

AFB – Air Force Base

AFMC – Air Force Materiel Command

AFOSR – Air Force Office of Scientific Research

AFSOC – Air Force Special Operational Command

ALC – Air Logistic Center

AMC – Air Mobility Command

AOA – Angle of Attack

ARPA – Advanced Research Project Office

CFC – Chloro Floro Carbon

CM – Countermeasure

CRDA – Cooperative Research and Development Agreement

DEA – Data Exchange Agreement

DEW – Directed Energy Weapon

DMSP – Defense Meteorological Satellite Program

DoD – Department of Defense

E-O – Electro-Optical / Optics

EELV – Enhanced Expendable Launch Vehicle

EPA – Environmental Protection Agency

ERINT – Extended Range Interceptor

FAA – Federal Aviation Administration

FAC – Forward Air Control / Controller

FLASER – Forward-Looking Infrared Laser Radar

FLIR – Forward-Looking Infrared

FPA – Focal Plane Array

FY – Fiscal Year

GaAs – Gallium Arsenide

GPS – Global Positioning Satellite

HazTox – Hazardous and Toxic

HCF – High Cycle Fatigue

HgCdTe – Mercury Cadmium Telluride

HTS - High Temperature Superconductor / Superconducting

IHPRPT – Integrated High Performance Rocket Propulsion Technology

IHPTET – Integrated High Performance Turbine Engine Technology

InP – Indium Phosphide

IR – Infrared

IRAD – Independent Research and Development

IRCM – Infrared Countermeasure

IRST – Infrared Search and Track

JDL – Joint Directorate of Laboratories

KEW – Kinetic Energy Weapon

LADAR – Laser Radar

LANTIRN – Low Altitude Night Targeting Infrared Navigation

lb – Pound

LCC – Life Cycle Cost

LO – Low Observable

LWIR – Long Wave Infrared

GLOSSARY

M&P – Materials and Processes(ing)

MAJCOM – Major Command

MAP – Mission Area Plans

MCT – Mercury Cadmium Telluride

MILSATCOM – Military Satellite Communication

MOU – Memorandum of Understanding

MTBF – Mean Time Between Failure

NDI/E – Nondestructive Inspection / Evaluation

NLO – Nonlinear Optical / Optics

OC-ALC – Oklahoma Air Logistic Center

ODC – Ozone Depleting Chemical

OO-ALC – Ogden Air Logistic Center

OSI – Office of Special Investigations

P3I – Preplanned Product Agreement

PCD – Polycrystalline Diamond

PE – Project Element

PL – Phillips Laboratory

RAM – Radar Absorbing Materials

RAS – Radar Absorbing Structures

RCS – Radar Cross Section

RF – Radio Frequency

RLV – Reusable Launch Vehicle

RPV – Remotely Piloted Vehicle

S&T – Science and Technology

SA-ALC – San Antonio Air Logistic Center

SAR – Synthetic Aperture Radar

SBIR – Small Business Innovation Research

SEA – Special Emphasis Area

SiC – Silicon Carbide

SLEP – Service Life Extension Program

SM-ALC – Sacramento Air Logistic Center

SPO – Systems Project Offices

STTR – Small Business Technology Transfer

TAP – Technology Area Plan

TBCCO – Thallium Barium Copper Calcium Oxide

TCC – Thermal Control Coating

TMP – Technology Master Process

TPAM – Technology Panel for Advanced Materials

TPIPT – Technology Planning Integrated Product teams

TR – Technical Report

UAV – Unmanned Aerial Vehicle

USAF – United States Air Force

USD/DDRE – Undersecretary of Defense, Deputy Director of Research and Engineering

UV – Ultraviolet

VOC – Volatile Organic Compounds

WL – Wright Laboratory

X-link – Cross-link

YBCO – Yttrium Barium Copper Oxide

$ZnGeP_2$ – Zinc Germanium Phosphide

ZnS – Zinc Sulfide

ZnSe – Zinc Selenide

TECHNOLOGY MASTER PROCESS OVERVIEW

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

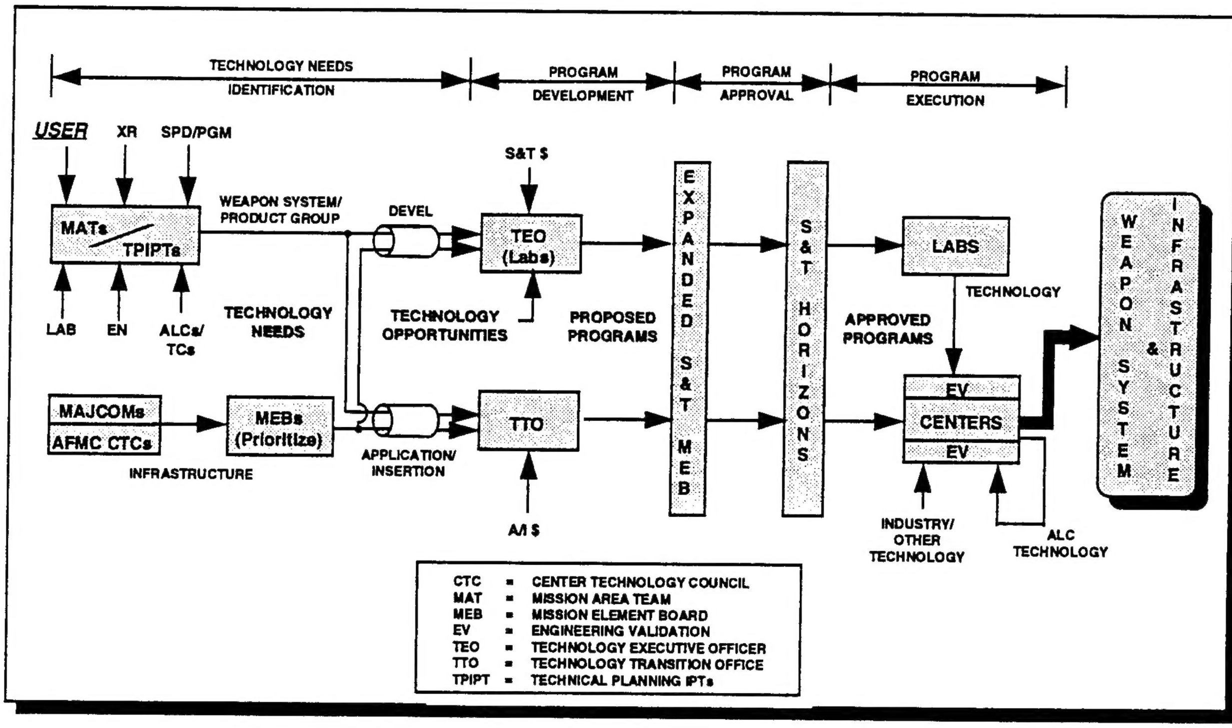


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification**--Collects customer-provided technology needs associated with both weapon systems/product groups (via TPIPTs) and supporting infrastructure (via CTCs), prioritizes those needs, and categorizes them according to the need to develop new technology or apply/insert emerging or existing technology.

Weapon system-related needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.

- Phase 2, **Program Development**--Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.
- Phase 3, **Program Approval**--Reviews the proposed project portfolio with the customer base via an Expanded S&T Mission Element Board and, later, the AFMC Corporate Board via S&T HORIZONs. The primary products of Phase 3 are recommended submissions to the POM/BES for S&T budget and for the various technology application/insertion program budgets.
- Phase 4, **Program Execution**--Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

TMP Implementation Status

The Technology Master Process is in its first full year of implementation. AFMC formally initiated this process at the beginning of FY94 following a detailed process development phase. During the FY95 cycle, AFMC will use the TMP to guide the selection of specific technology projects to be included in the Science and Technology FY98 POM and related President's Budgets.

Additional Information

Additional information on the Technology Master Process is available from

HQ AFMC/STP, DSN 787-7850, (513) 257-7850.

INDEX

INDEX